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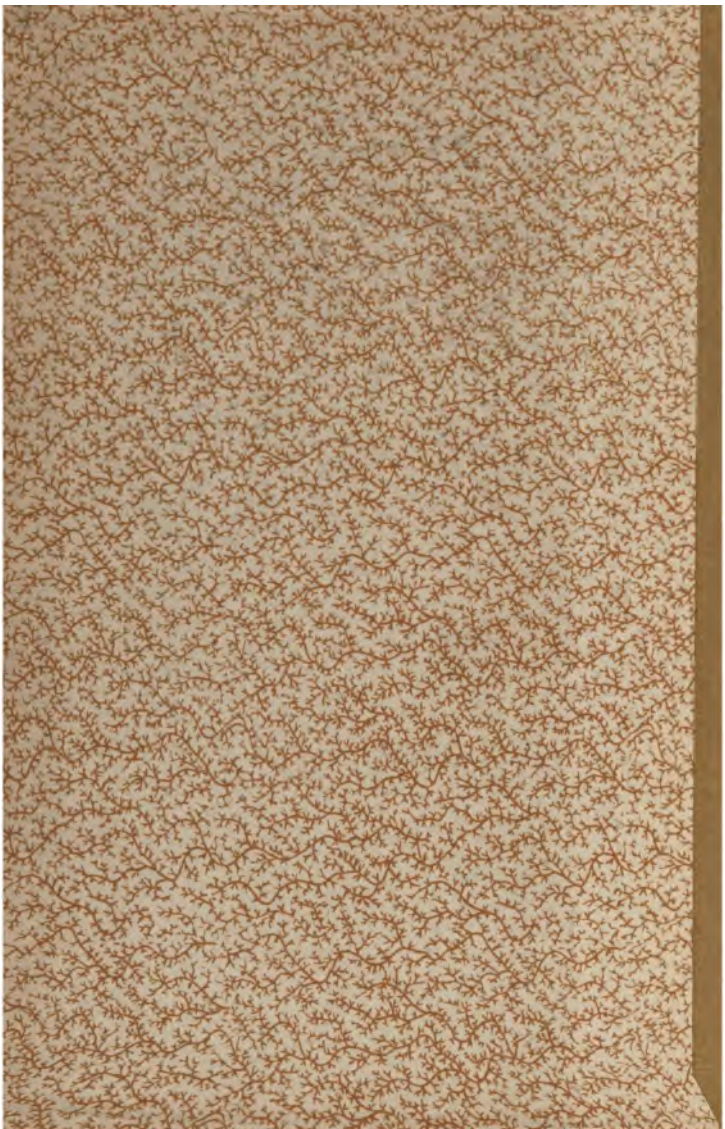
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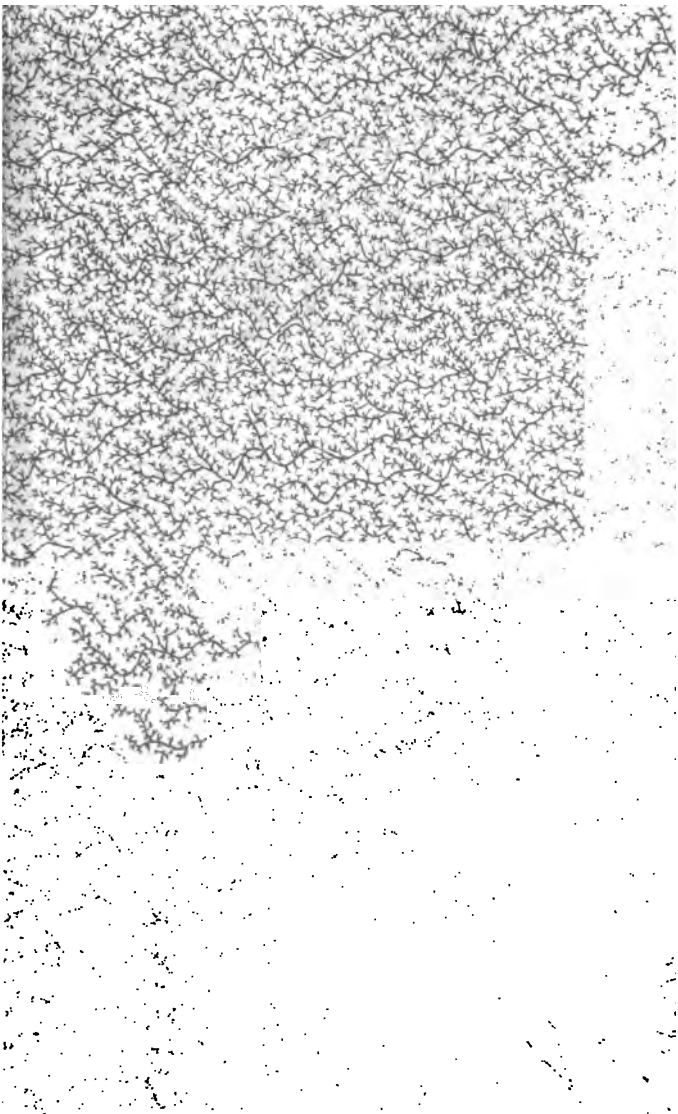
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BRITISH
MANUFACTURING INDUSTRIES.

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BRITISH MANUFACTURING INDUSTRIES.

EDITED BY

G. PHILLIPS BEVAN, F.G.S.

TOBACCO,
By John Dunning.

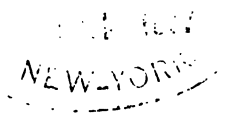
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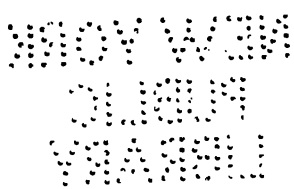
1876.


NEW-YORK

PREFACE.

THE object of this series is to bring into one focus the leading features and present position of the most important industries of the kingdom, so as to enable the general reader to comprehend the enormous development that has taken place within the last twenty or thirty years. It is evident that the great increase in education throughout the country has tended largely to foster a simultaneous interest in technical knowledge, as evinced by the spread of Art and Science Schools, Trade Museums, International Exhibitions, &c.; and this fact is borne out by a perusal of the daily papers, in which the prominence given to every improvement in trade or machinery attests the desire of the reading public to know more about these matters. Here, however, the difficulty commences, for the only means of acquiring this information are from handbooks to the various manufactures (which are usually too minute in detail for general instruction), from trade journals and the reports of scientific societies; and to obtain and systematize these scattered details is a labour and a tax upon time and patience

which comparatively few persons care to surmount. In these volumes all these facts are gathered together and presented in as readable a form as is compatible with accuracy and a freedom from superficiality; and though they do not lay claim to being a technical guide to each industry, the names of the contributors are a sufficient guarantee that they are a reliable and standard work of reference. Great stress is laid on the progressive developments of the manufactures, and the various applications to them of the collateral arts and sciences; the history of each is truly given, while present processes and recent inventions are succinctly described.



BRITISH MANUFACTURING INDUSTRIES.

TOBACCO.

By John Dunning.

The weight of tobacco imported into Great Britain and Ireland with the knowledge of the Customs authorities in 1871 was no less than 73,179,318 lb., and in 1872, 47,462,903 lb.; the declared value of these quantities, exclusive of duty, 6,126,185*l.*; the quantities cleared for home consumption in the two years, respectively, 42,656,658 lb. and 43,948,427 lb. The imports for the three years, 1873–4–5, inclusive, were 217,802,395 lb., of the total value of 10,764,908*l.*; the quantity cleared from bond for home consumption during the same period was 141,386,540 lb.; and the stock remaining in hand at the close of last year was 82,186,366 lb. It has been estimated that about 2,877,410,279 lb. of this product were smoked or otherwise consumed in the United Kingdom between 1800 and 1870, of the value of about 578,000,000*l.* The annual average allowance per head of the population, which was 13¾ oz. in 1841, 1 lb. 0¼ oz. in 1851, and 1 lb. 3½ oz. in 1861, had risen in 1871, with a total population of 31,724,000 persons, to 1 lb. 5½ oz.

per head; and in 1873, with a population estimated at 32,340,000, to 1 lb. 6¾ oz. per head.

The enormous duties imposed upon tobacco in this country, while they probably restrict the proportions of the manufacture, increase its importance. The duty in foreign countries does not exceed 3*d.* per lb., and in Belgium it is only one farthing a pound. The import tax levied in Great Britain is 3*s.* 2*d.* per lb. upon unmanufactured, and from 4*s.* 6*d.* to 6*s.* on manufactured, tobacco; and it ranges from 100 to 1800 per cent. of the value. The amount realized annually in the form of these duties increased from less than one million sterling at the beginning of the century to 7,421,315*l.* in the years 1874–5. The comparative importance of this item to the Treasury is seen, when we compare it with the total duties collected at all British ports in the same year, which amounted to 19,626,343*l.* There were issued in 1869, 597 licences to manufacture tobacco, and 284,124 dealers' licences. The duty paid by manufacturers ranges from 5 to 30 guineas, according to the quantity produced; the regular dealer's licence-duty is 5*s.* 3*d.*; and occasional licences for special retail sales are issued at the rate of a few pence per day. The amount of duty on licences that year was 85,057*l.* 1*s.* 3*d.*, and at present it may be said that tobacco contributes one-tenth of the whole revenue of this country.

In order to secure the payment of these duties and to control the manufacture and sale of this article, Parliament has created many and voluminous statutes, with heavy penalties for breach of their provisions;

and the trade has occupied much of the time and attention of Royal Commissions, Government Boards, and a large body of Customs and Excise officials, including a highly trained staff of scientific experts, who test with chemical and microscopic appliances the manufactured and unmanufactured leaf submitted for their examination by Her Majesty's Inspectors. The peculiar exigencies of this branch of industry have led to practical modifications of the Factory Acts and the laws relating to Sunday labour, especially as they apply to the employment of women and Jews. The principal of these measures is an Act passed in 1842, to amend a previous statute entitled, "An Act to Discontinue the Excise Survey on Tobacco, and to Provide other Regulations in lieu thereof;" and will have to be noticed in connection with the subject of adulteration, to check which its main provisions were designed. All importers are required by law to deposit the tobacco brought from abroad in the bonded warehouses at the few ports of the United Kingdom where the import is allowed. The chief of these are in the Victoria Docks, London, and the King's Dock, Liverpool, where the bulk of the imported leaf is to be found, and whence none is removed until it has been examined, weighed, and approved, and the duty paid. The London warehouses are vast fire-proof buildings, with a floorage of about fifteen acres; and I have seen stored in them at one time more than a hundred thousand packages of tobacco—hogsheads, bales, and boxes—weighing from 17,000 to 18,000 tons. In the Liverpool warehouses on one occasion I saw nearly 23,000

hogsheads of American tobacco alone; and it was calculated that these, if placed in a line, would extend over 21 miles, and that the tobacco they held, if spun into "twist," would have made a rope more than 171,000 miles in length. I stood in the midst of the produce of 30,000 acres of land, reckoning 1200 lb. avoirdupois to each acre; and the quantity of smoking material stored there at that time was no less than 24 millions of pounds in weight.

Mechanical invention on the one hand, and forgery of brands on the other, furnish evidence of the extent to which the tobacco industry has taxed human ingenuity in this country. In the "Abridgments of Specifications relating to the Preparation and Use of Tobacco," published by authority of the Commissioners of Patents in 1866, and including all the inventions in this class enrolled since 1721, there are detailed more than 300 contrivances for the improved manufacture, or more convenient use, of the tobacco leaf. Of these, about 60 relate to machinery used in cutting smoking varieties, spinning twist, pressing cake tobaccos, and grinding snuffs; and more than 30 are for making cigars, besides several specially applied to the preparation of cheroots and cigarettes. Since 1866, very many most important inventions have been added to the number, one or two of which have effected great improvements in the work of the factories. With regard to brands, so extensive and lucrative was the forgery of the names, titles, and distinctive marks of favourite tobaccos and cigars, that

a few years ago a powerful association, formed for the purpose of repressing this abuse, had to carry 150 suits through Chancery before the system could be in any effectual measure put down.

I have been favoured by Mr. John P. Walker, Secretary to the Cigar Makers' Mutual Association, with an estimate of the number of persons employed in this manufacture in Great Britain. It is not practicable to obtain accurate figures; but these are approximately correct. In round numbers, then, there are about 1900 men, 2000 women and girls, and 1900 boys, constantly engaged in making cigars. It is not improbable that they make at least a million cigars per day. About 800 men are employed in making and spinning tobacco; and if this number seems small, it must be remembered that in some instances a cutting machine (such as Legg's), guided by one man, will turn off 200 lb. of fine shag, or 600 lb. of rough smoking fibre, in an hour. Including men, women, boys, and girls, whose business is to strip the stem from the leaf, or to make up cigars in bundles, employés called mess-pickers, and some others, Mr. Walker gets a round total of 7000 or 8000 workers in tobacco; without counting the hundreds of clerks, counter-men, carmen, packers, and others, who are as necessary as these to the work of the factories, or the thousands who are indirectly engaged in the same branch of industry. In one cigar-making establishment—that of Messrs. Cope, Brothers, and Co., at Liverpool—about eight hundred hands are employed.

Six hundred of these are women and girls, who are capable of excellent work. A first-class tobacco-cutting factory, such, for instance, as Hill's, in Shoreditch; Wills's, at Bristol; Harvey's, at Newcastle; Jackson's, at Leeds, and some others, will produce 5000 or 6000 lb. of smoking tobaccos per day. Wages vary greatly, according to the quality and quantity of work, piece-work being the rule in cigar manufacture. The best cigars are made by men, who sometimes earn as much as 3*l.* per week; but the average rate of men's wages in this department may be taken at 25*s.* a week. One pound a week is a good average amongst women; some, skilful hard-working cigar-girls making as much as 25*s.* 6*d.*, and others not more than 15*s.* Many young girls, beginning at 2*s.* a week, will reach 7*s.* before the end of their first year, and 10*s.* or 12*s.* before they are out of their apprenticeship. Tobacco cutters make from 28*s.* to 30*s.* weekly. A skilful spinner will occasionally make from 50*s.* to 3*l.*; but this is rare.

The chief sources of tobacco in Europe are Germany, Holland, Salonica, Hungary, and Russia; in Asia, the principal are China, Japan, the East Indies, Latakia and other parts of Asiatic Turkey, Persia, Java, Syria, and Manilla; in Africa, Algiers; in South America, Varinas, Brazil, Uruguay, New Granada, Paraguay, Cumana, and other fields are most productive; while the great tobacco districts of North America are the United States, Mexico, Cuba, Hayti, and Porto Rico. The extent to which these and others are severally laid under contribution by the manufacturers

of this country is shown by the following partial analysis of the imports of 1873 and 1874:

From	1873.	1874.
	lb.	lb.
Germany	687,720	856,646
Holland	5,429,511	7,356,798
France	1,436,985	1,712,839
Greece	330,712	84,161
Turkey	1,430,572	696,132
British India	3,068,109	2,359,987
Philippine Islands	171,803	780,098
China	2,136,637	1,398,467
Japan	4,846,892	2,948,036
Spanish West India Islands	295,654	242,304
New Granada (United States of Columbia) ..	2,199,885	1,617,573
Argentine Republic	340,787	663,940
United States of America	57,593,826	53,567,555
Other countries	1,404,640	1,890,679
Total imports ..	81,382,733	76,175,215

It will be observed that by far the greatest quantity is brought here from the United States. The crop raised in the States in the year 1872 reached the enormous total of 259,480,000 lb.; and the 'New York Tobacco Leaf' says that for the comparatively small quantity which we import from that country, we pay to our Government more than twice as much money as the American producer realizes for all the tobacco exported from that part of the world. A serious drought in 1873 inflicted a blow upon the tobacco-raising industry of that country from which it has not yet wholly recovered. The leading varieties sent here from the United States are those of Virginia,

Kentucky, Missouri, Connecticut, Ohio, and Maryland; all of which have distinct values and peculiarities. In the Annual International Exhibition at South Kensington in 1872 there was exhibited by Messrs. Bramble, Wilkins, and Co. a large case containing specimens of nearly every known variety of leaf, in which the curious might note the diversities and similarities of size and shape, strength and arrangement of rib, coarseness or fineness of fibre, and other peculiarities which variously distinguish the several growths. In addition to such as have been named above, this case contained specimens from Canary, Roumelia, Moldavia, Poerbolinge, Rio Grande, Palmyra, Arracan, &c. The species are very numerous—more than forty are known; and although they have a general likeness, the differences are so many and so marked that the unpractised botanist would be unlikely to class them in the same family. It is a singular fact, but established beyond doubt by frequent experiment, that, while change of soil and climate effects little alteration in the botanical character of any of these varieties, it makes the greatest difference in their chemical composition; so far, at least, as depends upon their mineral constituents. Not only does the chemical composition vary according to the botanical structure, the geographical habitat and the rearing conditions of the leaf, but it changes considerably during the process of drying, curing, and manufacture. Dr. Murray and others classify the components of the dried leaf thus: Nicotine (a liquid alkaloid), from 2 to 9 per cent.; nicotianine (an aromatic essence), about 2 grains per lb.; a bitter extractive *principle;* a yellow oil and some fatty matter;

gum and mucilage; tannin and gallic acid; woody fibre; salts of lime; potash; magnesia; soda and ammonia; silica or sand; and moisture. In drying, the leaf parts with 88 per cent. of water. During the fermentation which takes place in curing, nicotine and nicotianine are secreted from the juices of the leaf; and during the further fermentation in the manufacture of the dried tobacco, these properties are often dissipated, and carbonate of ammonia is largely produced. In smoking, oil and ashes are formed, the latter in the proportion of about 20 per cent. of leaf; and the smoke, when analyzed, is found to consist of nicotine, empyreumatic vapour, resin and oil, ammonia, carbon, carbonic acid, carbonic oxide, hydrocyanic (prússic) acid, sulphuretted hydrogen, carburetted hydrogen (fire-damp), paraffin, and watery vapour. The salts regulate fermentation during curing or manufacturing, and ensure the proper burning of prepared tobacco. Albuminous substances, which amount to 10 or more per cent. before curing, are obstacles to burning, and it is the chief end of fermentation to get rid of them. The conditions of soil and climate which favour the production of nicotine are precisely those which are unfavourable to the valued aroma. A given variety of tobacco will either be strong, with slight aroma; or highly aromatic, and weak in nicotine, according to the soil and climate in which the plant is grown. Havana, Manilla, and other favourite cigar-varieties have from 2 to 3 per cent. of nicotine; Turkey, Syria, Latakia, and similar tobaccos, only 1 to 2 per cent.; while Kentucky and Virginia have 6 to 7 per cent., and *French leaf* has been known to contain as much

as 9 per cent. Real Havana, of which comparatively little is grown and much less reaches this country, is principally, if not entirely, made into cigars. Virginia is the favourite variety for cavendish, negrohead, and black twist, and is largely used for returns, shag, and snuff; Kentucky, Missouri, and Ohio for cavendish, brown twist (such as pigtail), Bristol bird's-eye, returns, and shag; Dutch and German for the commonest cigars, K'naster, moist snuffs, and smoking mixtures; Java and Japan for light cigars, mixtures, and light moist shag; Latakia, Turkey, Lynchburgh, Paraguay, Brazil, and the rest for cigarettes, mixtures, imitations, and substitutes. The prestige of Havana tobacco has very nearly died out; Manilla, which is far cheaper and more abundant, having done much, with its sweetness of flavour and excellent burning qualities, to supersede it; and German, which costs fewer pence than Cuban costs shillings, is increasing in favour.

The leaf arrives in this country dried and cured, made up in "hands" (bundles which are technically so called), packed in hogsheads, bales, or boxes, made of various materials according to the lands from which they come. Thus, the bales from South America are secured in stout hides of cattle, which are there too abundant to be costly. The hogshead made of wood is naturally preferred by the exporters of North America and the West Indies, where timber is plentiful. The Asiatics employ strong coarse cloth of hemp or flax, or plaited matting, and in some cases wrappers of woven camel's hair. The sorting of the leaf and making it into "hands" are the last of the long series of difficult *processes by* which the planter prepares his harvest for

the market. The whole course of rearing and curing tobacco is a system of applied science, compared with which most other and cognate branches of agriculture and preparation of vegetable products are simple and easy. With this we have little concern beyond the fact that upon the scientific knowledge, mechanical skill, and scrupulous care which the planter brings to bear upon his preliminary labours, at least as much as upon the like qualities exercised in the subsequent manufacture, the value of the smoking and chewing tobaccos and the snuffs of commerce depends. As the organic substance of the leaf undergoes decomposition and chemical transformation in curing, it will be understood that only the most incessant watchfulness and the most delicate manipulation can ensure the result which is satisfactory to the purchaser. The slightest error in drying, in time and extent of fermentation, mode of sorting, arranging, or handling, may spoil a whole package or a whole crop. Arrived in the bonded warehouses of this country, every hogshead or bale is opened, that the importer may be satisfied as to the quality and condition of his purchase, and the net weight taken for the calculation of the Customs duty before removal; the waste, which is sometimes large, being consigned, with the sweepings of the warehouses and impounded smuggled tobacco, to the "Queen's Pipe," a furnace appropriated to the destruction of such tobacco as is unprofitable to the Treasury—and therefore an institution of doubtful value.

The manufacturer's first business is to separate the leaves. In order to do this without breakage, it is *necessary to moisten* the "hands"; for, although it is

said to be impossible to reduce the moisture below 10 per cent., yet even a much larger proportion is required to render the leaf pliable. To save repetition, I may remark here that in Great Britain the use of any liquid or substance whatever, except water (in the case of certain snuffs alone a little salt, alkaline salts, lime water, and oil being permitted), is forbidden by law, under heavy penalties. In other countries liquors or "sauces" (as they are called) are generally employed for this and for other processes. In the French Government Manufactory in Paris, a solution of one part of sea salt in ten parts of water is used to give suppleness to the leaf; and sometimes sal-ammoniac, sugar, and other ingredients. The salt is said to be effective in checking putrefactive fermentation; but in this country manufacturers are made to rely on their knowledge, care, and experience for the controlling of fermentation. The process of damping completed, the leaves are spread out singly; the central rib of each is removed by hand, and the right and left halves thus divided are smoothed and laid in separate piles. The largest and strongest leaves are selected for cutting and spinning; the most perfect in form are reserved for the "wrappers" or outside folds of cigars; broken or defective leaves are used as "fillers" or insides of cigars; and the rib, or central stalk, of the leaf is ground into snuff. This work of stripping and sorting the leaves is generally done by girls and women, and simple as the operation appears, its proper performance requires a degree of dexterity to be attained only by long experience. In removing *the rib, it is* difficult to avoid tearing the leaf, which

seriously deteriorates its value. The more perfect the form of the leaf used to fill the cigar, as well as for its envelope, the more evenly will the cigar burn; and the less torn the leaf used for cutting, the longer and finer will be the fibre of the shag.

Tobacco cutting is the process by which the fermented leaf is prepared for the pipe and the cigarette. "Shag" is the generic name of all those varieties of leaf which have passed through the cutting machine; except "cut cavendish" or other cake tobacco, so cut to save the smoker the trouble of using his own knife. "Bird's-eye" differs from the other kinds of shag only as far as it retains a greater proportion of the rib of the leaf. As the leaf passes under the blade, it is cut transversely; and the horizontal section of the mid-rib or central vein, which is of a woody tissue and lighter in colour than the softer portions of the leaf, gives the distinctive name to this variety. There have been many mechanical contrivances for cutting tobacco, several of which may be found at work in English factories; but it will be necessary to describe only one, because it is in much more general use than any other, and possesses all those peculiarities which have been most approved in the rest. I select the "Combined Pressing and Cutting Machine," patented and manufactured by Mr. Robert Legg, of London; which is now employed in forty-six London houses, all the Bristol factories, most of those at Liverpool, Birmingham, and other large towns in the country; and in the Government manufactories of France and Portugal, besides many large establishments in Germany, Russia, South America, the Aus-

tralian Colonies, and elsewhere. This machine, receiving the bulk of the leaf in a trough or feeding box, draws it inwards between rollers, which subject it to sufficient pressure to make the mass firm for cutting. The lower roller is of large diameter and made of wood, so as to form a cylindrical chopping block, on which the knife descends. The upper rollers are small and made of metal. They press the tobacco onwards from the feeding box to the knife, but are so fitted as to yield, according to the thickness of the "feed." The rollers revolve in unison with the strokes of the knife, regulated by ratchet wheels, which determine the fineness of the shreds into which the leaf is cut. One of the largest of these machines, driven by 2 horse-power, will make 300 cuts per minute and turn out 200 lb. of fine "shag" of the best English make, or 400 lb. of the description called "French-cut," or 600 lb. of "German smoking," in a single hour. The action of the knife is similar to that of a chaff-cutting machine. The cut tobacco when removed from the machine is placed on a tray, heated by gas flames, and there tossed and shaken by hand, until it is sufficiently lightened to be fit for smoking. Before the introduction of this apparatus, two processes were involved in the operation; or, rather, a screw or hydraulic press had to be employed to give density to the mass of damp leaf, before it could be brought under the cutter. The manufacture is simplified, and considerable saving of labour and improvement in quality effected, by Mr. Legg's invention. The chief difficulty to be overcome in all *attempts to* expedite tobacco-cutting is the clogging

of the machinery by the mucilaginous juices of the leaf; and the strict Excise regulations, whose purpose is the prevention of adulteration, forbid the admixture of any substances that might reduce the obstacle. As long ago as 1747, a cutting machine, composed of two knives and a crank, was patented by a person named Sage; and of late years many various contrivances have been produced, all more or less ingenious; but the machine here described represents the highest improvements yet effected in this department.

"Roll" or "twist" is a preparation of tobacco which is made by first spinning the leaf into the form of a rope or cord, and then subjecting it to pressure. There are several varieties, some thick and coarse like "pigtail," or "Limerick twist," which is intensely black in colour; and others thin and of finer grain, sometimes called "ladies' twist," or—because of its lighter hue—"brown twist." Until very recently, the only mechanism used in the manufacture was a simple wheel turned by hand; and the process was almost precisely similar to that through which a man and a boy pass "tow" in a village ropery. The whole method, as it may still be seen in London factories, is described with sufficient accuracy in an account of "pigtail" making in a French workshop, given in Tomlinson's "Cyclopædia." "The leaves," says the writer, "are spun into rope or cord at a long bench, at one end of which is a spinning wheel, turned by a boy. A second boy arranges the leaves in a line along a bench, making them overlap; and a man standing between the two boys, rolls up the leaves into a kind

of cylinder, into which the boy at the wheel throws the desired amount of twist. When the length has been spun, it is wound upon a reel, to be afterwards made up into balls, which are pressed, dried, and packed." These balls or coils, the form of which has never been changed since tobacco manufacture became one of the industries of this country, are the familiar signs of tobacconists' shops, as common as the grotesque negro dwarf and the wooden Highlander. The 'Tobacco Trade Review,' under date 1869, says Messrs. Cope were the first to apply steam power to the spinning wheel, by means of a pulley and strap; and that "instead of monopolizing the contrivance, they placed it at the service of the trade, before the Factory Acts interfered with the employment of children in tobacco factories." But, as early as 1862, Mr. T. C. Barraclough registered "a communication from Ernst Breul," including a specification of machinery for spinning, twisting, and rolling tobacco; and since that time several machines have been patented and used. Amongst the best-known recent inventors in this department are Ward and Block, Ronald and Co., Cope and Lauder, Mr. Archibald Reed of Arbroath, Goodbody and Donovan, Gillan and Crawford, and others; but for the latest and greatest improvement we have again to turn to Mr. Legg, of the City Engine Works. This machine not only, like all the best of the others, performs the whole operation of converting the leaf into compact twisted rope, and coils it upon bobbins as it is made; but, by virtue of a beautifully delicate appliance, the rate at which the rope is twisted, and the rate at which the twisted rope is coiled upon the bobbin, are

made to regulate each other. It is distinguished from other spinning machines by a differential traverse movement, the object of which is to lay on the coils at a rate always governed by their own thickness. Of the two moving parts—the twisting apparatus and the coiling apparatus—one is always turning more rapidly than the other; and the difference between them cannot be uniform, because of the increasing diameter of the bobbin as it fills, and also because of the slight but unavoidable variation in the thickness of the rope made. The traverser is founded on this varying difference between the velocity of the spinner and that of the coiler; and it prevents breakage, regulating each part of the work by reference to the other part. It is self-acting and is always in the right position: whether to stop the machine, to start it, or to turn it backwards, the traverser controls the feed gear and the storing gear, and compels them to move in unison. This will be enough to show what immense strides have been made within a few years from the primitive standpoint of the man with two boys and a wheel. The coils, when completed, are subjected to enormous pressure—in some cases amounting to a weight of 30 tons to a surface of one square yard; first, to give the required density and hardness to the roll, and, next, to force the juices uniformly through the mass of rope, and give to every part an equal colour. Numerous contrivances are applied by as many separate makers to this end; and the "roll," thus pressed, is ready for sale.

"Cavendish," properly so called, was until recently a forbidden *manufacture* in this country—its importation having been legalized only as lately as 1863; and,

so long as the Excise laws exclude sweetening matter from the preparation of tobacco, it is not likely to become general. Under a special Act of Parliament, the Richmond Cavendish Company (Limited) is permitted to produce sweetened cake-tobacco; but as all its operations are carried on in bond, under the constant supervision of the officers of the Revenue, the manufacture is limited. Nevertheless, in one year (1867) about 125 boxes were cleared from these works for home consumption; whereas the total quantity of foreign cavendish, upon which duty was paid during the same period, amounted to 26 boxes. The finest American sorts consist of Virginia leaf, cured in the ordinary way, with the addition of a little molasses or sugar and other flavourings, and pressed into cakes of various sizes. Where, as in the Richmond Company's Works, at Liverpool, the sweet ingredients are added, there is no essential distinction between the foreign-made and the British-made article. In that case, also, the duty is proportionate. But unsweetened cavendish is produced in various factories under the same regulations as apply to the other kinds, such as twist or shag. In this case, the tobacco is quite equal to foreign cavendish for all smoking purposes; but chewers prefer the sweeter taste of that which is prepared with molasses. The process of manufacture is exceedingly simple; but to meet the mechanical difficulties attendant upon expelling air and moisture from the leaf, and forcing the fibrous particles into a more or less homogeneous mass, various hydraulic and other contrivances have been brought into play. The leaf, having been "sweated" for a day or two, is worked

into a soft mass, and then placed in moulds and shaped into squares or oblongs by screw-pressure. The earliest mechanism patented for this purpose was that of Mr. Thomas Cope, in 1860, of which the official description published by the Commissioners of Patents says: "The patentee presses 'shag tobacco after it is manufactured, and also shag smalls or both of them mixed,' by means of dies and sinkers, into cakes." Three years later, Messrs. John and J. S. Harvey introduced a cast-iron trough or box, divided into spaces of the size of the cakes required, and fitted with knives and screws to cut the tobacco and secure it as cut; and in 1865, when the manufacture of cavendish was legally recognized, Mr. William Davies patented an apparatus for rolling tobacco into large cakes and then dividing them into "plugs" by means of knives or dies. There are other methods, but it will be sufficient to notice that which is adopted in Cope's large factory and in the Richmond Cavendish Works. The wet tobacco mass, having been pressed into moulds, to ensure uniformity of weight, until the parts adhere firmly together, is taken in hand by girls, who enfold it firmly in wrappers of perfect tobacco leaves. The cakes are then passed through a series of other moulds, each smaller than the last, increasing pressure being employed by hydraulic power, until each cake or "plug" is turned out dry and hard, ready for the ornamental wrapper which finally receives it. By this time the juices of the various component portions of the mass have been distributed evenly through the whole lump, giving it the rich dark colour which smokers prize. Those kinds *of cavendish* which are lighter in colour are pre-

pared in precisely the same way, except only that they are worked in a drier state.

In giving some account of the manufacture of cigars, I may be allowed to point out the fallacy which lies at the root of the popular preference for the cigars of Havana. It will be granted that some Cuban tobacco is the best tobacco, and of course, when worked by the best manipulators, makes the best cigars. But it cannot be said that the cigar makers of Cuba are more skilful than those of Great Britain, or that they have a monopoly of the best tobacco. I have already shown how small a quantity is imported to this country from Cuba in any shape, and it is notorious that much of that which is exported from Cuba is not grown there. Cargoes of leaf are shipped to Cuba from America and from Europe, manufactured into cigars there, and sent back as "Havana Segars" to the countries where the leaf was grown. Of real Cuban there are many varieties, according to differences of soil and culture; and that all Havana tobacco is not equally good is proved by the fact that some sorts will sell upon the spot for twenty times as much money as others. The Cuban manufacturer has the advantage of being on the market, and can, if he will, secure the best leaf; and he is allowed to use what sauces or flavourings he pleases in making cigars. To these is to be attributed the superior colour or gloss, and the delightful fragrance, which characterize the Havana cigar when first brought here; but, even when the leaf and the make are the best, there is no superiority over the best British-made cigar, when the Cuban flavourings have *been dissipated* by a few days' exposure to the air. In

skill, the British cigar-maker can match the world; and, as to quality, it is the interest of the manufacturer to import the best tobacco that his customers will buy.

The cigar maker, when at work, is seated at a bench or table; and his tools are a sharp knife, a gum bottle and brush, and a flat square piece of wood called a cutting board. He spreads upon the cutting board a perfect half-leaf of tobacco, trims it with his knife into the shape that will most conveniently form the wrapper or envelope of a cigar; takes in his right hand a bunch of less perfect leaf or "filler," and rolls it into a long oval form with his fingers; then encloses it tightly in the wrapper, rolling the cigar under his left hand till the taper end is formed, gums the leaf firmly at the tip, and cuts the blunt end squarely with his knife to complete the operation. Expert workers are able to gauge the requisite quantity of leaf for each cigar so accurately, that the weight given out for a pound of medium size is seldom found to exceed or fall short of the required hundred, strict uniformity of appearance being preserved. Many machines have been devised for performing this work; but none altogether supersede hand labour or have come into general use. In Cope's establishment, where several hundred girls are employed in cigar making, the less experienced are furnished with a patent gauge, to enable them to regulate with accuracy the size and proportions of each cigar; but older hands are independent of such assistance. In England the employment of women and girls in this branch of industry is of recent date; but it is growing, and has been not less successful than in Manilla, where about 25,000 women are thus engaged

in the Government factories. English women who remain long at the business acquire great aptitude and make good wages; but the highest classes of cigars are still made by men, even where, as at Cope's, the employment of women is a speciality. The cigars, when made as described, are examined and sorted according to the shade of colour in the wrapper. "Full-flavoured," "medium," and "mild" may thus come out of the same batch of material, the distinction lying in the greater or the smaller pungency of the outer leaf. Having been sorted, they are tied in bundles with slips of ribbon, placed in cedar boxes, labelled, closed up, and sent to the drying room, where they remain until sufficiently seasoned for smoking. Some qualities of tobacco attain perfection by preservation in an ordinarily dry atmosphere; but others are brought to their best condition by artificial heat. The time of drying varies from a few days in some cases to many months in others.

Although many millions of cigarettes are made annually for the trade in England (many millions more being imported from the Continent), the mode of their manufacture is so simple, as to require only a passing allusion. Most kinds are mere wisps of light tobacco rolled in paper. Some are more substantial, and are filled with the stronger shags prepared as for pipe-smoking; and others again are dainty tubes of tobacco grains, almost as fine as snuff. There have been several attempts to substitute mechanical means for manipulation in this branch; but hand-made cigarettes retain their popularity. Some manufacturers employ Greek and other foreign artistes to

make their papillettes and cigarettos, and these exhibit marvellous dexterity in enfolding spoonfuls of golden tobacco-dust in pieces of chemically-prepared tissue, and fixing the wrappers with glue; but there is no difficulty in the process to render the importation of such talent a necessity. Machines with fine circular saws for cutting the papers, and with rollers and travelling chains for completing the cigarette, and contrivances for impregnating the wrappers with tobacco juices and decoction of the leaf, are amongst the registered inventions. Cigarettes have been made entirely of such paper; at least one patent—that of Etienne Roche, March 1859—having been taken out for the purpose. By his process a compound of crushed tobacco leaves and ribs, rags and glue or glycerine, was made into thin sheets, designed either to wrap tobacco in the form of cigarettes, or to be rolled by itself into the form of cigars. Gauze tubing, indiarubber and glass mouthpieces, and other fanciful additions have been numerous. But largely as the demand for cigarettes has increased of late, the taste for this effeminate form of smoking material is an exotic little likely to be naturalized amongst us.

Snuff is the only other preparation of tobacco manufactured upon an extensive scale in Britain. There are large mills worked by steam and water power, which attest that the consumption is immense. One of these in Scotland used to grind 7000 lb. of snuff a week; and in English factories it is common to see several "mulls" at work, each producing about 30 lb. a day. These "mulls" are large conical iron mortars, *lined with wood*, and the tobacco is ground in them

with heavy pestles, driven slowly round until the mass is reduced to dust of the required fineness. The stalks and leaves intended for this purpose, after being chopped small by hand or machine, are formed in heaps, moistened and covered with cloths, in warm rooms, and left to ferment for several weeks before they are fit for grinding. After high fermentation, the mass is treated as a "stock," or basis for all kinds of snuff. For rappee varieties, such as "Prince's mixture," or "Macobau," it is ground at once; and for lighter kinds, such as "S.P.," it is dried before being put into the "mulls." In some mills there are also troughs, in which the coarser kinds are ground by revolving granite millstones; and ovens for roasting that which is intended for "Lundy Foote," or "Irish Blackguard." The varieties are many—eleven being made in one establishment; but these depend for their differences upon the flavourings with which they are "doctored," more than upon any special characteristic of the tobacco, or peculiarity of its preparation. It has been calculated that the quantity of snuff used in this country is about 500 tons per annum; and it is said that one retail shopkeeper in Lancashire sells 4 cwt. per week in pennyworths to cotton operatives.

Tobacco is boiled, at the Richmond Cavendish Company's Bonded Works in Liverpool, to make a wash for sheep. As much as 28 cwt. has been boiled down on the premises in a single day; and on one occasion the Mersey authorities were put to much perplexity and trouble by the difficulty of sinking a mass of the refuse, which had been sent out to sea, and persisted in *floating back* with the incoming tide. There were

about 50 tons of it, and days passed before it could be induced to disappear. The decoction of tobacco is adulterated with sulphate of copper, turpentine, and salt as soon as it is cool, and the exhausted leaf partially destroyed (de-nicotised) with quicklime before leaving the boiling house, under the direction of the Customs. This prevents either the wash or the refuse from being used in tobacco manufacture afterwards. Each gallon of the sheep-wash contains the essence of 24 ounces of strong American leaf. The preparation, which is allowed to be sold free of duty, has found favour not only amongst breeders of sheep, but amongst agriculturalists and gardeners, as an effective vermin-destroyer.

Notwithstanding the stringent enactments of the Legislature, the adulteration of tobacco is very common. The enormous duties added by the State to the cost of tobacco are a strong temptation to the use of cheaper materials, when these can be easily disguised or with difficulty detected; and the real advantages to be gained in the manufacture by the employment of certain "sauces" are an additional inducement to the breach of the law. Any person using any substance but water in the making of smoking tobacco; any but water, common salt, and a certain proportion of alkaline salts, or lime water in snuff; or other than oils in roll tobacco, is liable to a penalty of 300*l.* for each offence, under the Act of 5 and 6 Victoria. The same statute provides a fine of 200*l.* for receiving, sending out, or possessing, tobacco or snuff otherwise manufactured; and for using or having in a tobacco factory *any sugar, honey*, leaves, or other substances

capable of being used as substitutes for tobacco, or to increase its weight. It is clear, therefore, that no such flavourings as are used by foreign makers of cigars and smoking tobaccos can be safely employed here; but that the use of otto of roses, essences of lemon, bergamotte, geranium, and verbena, Tonquin beans, and oil of pimento, in the manufacture of snuffs is legitimate. Yet whole volumes might be filled with details of the adulteration carried on in spite of the rigid regulations of the Excise. When what is called "cheap shag" can be bought at 2*s.* 8*d.* and even 2*s.* 7*d.* per lb. in the market, it is evident that it cannot be all tobacco which has paid the duty of 3*s.* 2*d.* per lb., especially as a sound tobacco leaf from which good shag can be made, can scarcely be got for less than 8*d.* per lb. Even when the worst and driest qualities of Javanese or Japanese leaf are used, and water is the only added substance, the enormous percentage of moisture effectually ruins the tobacco. All the adulterations employed are not, however, so harmless as water. Dr. Ure analyzed a sample of snuff which contained pearlashes, to make it pungent and absorbent. Professor Hunt, the editor of "Ure's Dictionary," declares that large quantities of refuse leaves and roots, such as senna and rhubarb, after their medicinal qualities have been extracted by the druggist, are ground, coloured with burnt sienna or yellow ochre, made pungent with ammonia, and sold to the snuff makers. Irish roll, which used to come into the market at 2*s.* 10*d.* per lb., or 4*d.* less than the duty, puzzled the Excise officials, till the Irish manufacturers, being at last undersold by *English* competitors, revealed the secret that starch

was liberally employed, to enable the roll to take up an abnormal quantity of water. 1267*l.* 10*s.* was recovered in penalties for this offence in 1868, the duty on tobacco forfeited being about 4000*l.* The officers of the Laboratory maintained at Somerset House since 1842 have been very successful in detecting adulteration by the aid of chemistry and the microscope; and the Commissioners of Inland Revenue, in their elaborate report of 1870, in which they reviewed their work from 1856 to 1869, inclusive, expressed the opinion that adulteration was seriously checked. But they confess, "the adulterants are so varied, and the inducements to fraud so great," that "only well-directed and sustained efforts can prevent it." In their Fifteenth Report it is stated that, during the year 1872, of 232 samples of tobacco submitted for examination by the Excise officers, 174 were found to be adulterated; the adulterants being starch, rice, liquorice, gum, logwood, caramel, sugar, and salt of iron; the amount of adulteration ranging up to 4 per cent. rice and starch, 44 per cent. liquorice, and 5 per cent. gum. Their Seventeenth Report shows that out of seventy-one samples presented for examination by the Excise in the year ending March, 1874, fifty were adulterated; and bisulphite of lime is named amongst the adulterants detected. Mr. Henry Prescott's valuable book on "Strong Drink and Tobacco Smoke," written to show the practical use of the microscope in detecting such adulterants, states that leaves of dock, burdock, chicory, foxglove, and comfrey, are mixed with and substituted for tobacco; and that snuff is adulterated *with starches of* cereals, peameal, bran, sawdust of

various woods, malt rootlets, fustic, oxides of iron and lead, and ground glass. Amongst other instances, Prescott gives one of the seizure of some tons of chicory leaves steeped in tar-oil, which were used as fillers for "pure Havana cigars;" and one in which "the acorn cup of a large species of oak, Valonia, growing on the shores of the Mediterranean," was "extensively used in the adulteration of high-dried snuff." The Commissioners mention peat-moss, lime, magnesia, albumina, sand, and even chromate of lead, as adulterants; but they say that the last-named ingredient has not been detected for some years. They also give indigo and lampblack amongst the articles used to vitiate tobacco. Besides all these, elm, coltsfoot, plantain, beech, barleymeal, oatmeal, nitre, endive, cabbage, lettuce, thorn-apple, stramonium, sago, orris root, the seed of yellow flag, and common wheat-flour, have been used to eke out the spare supply of genuine tobacco allowed by the adulterating manufacturers. The collection of specimens of acknowledged adulterants in the tobacco section of the International Exhibition of 1873 included those mentioned already, with the addition of red ochre, sumach, burnt umber, Indian corn, Brazilwood, and carbonate of soda; and samples of the tobacco as adulterated were shown, side by side, with cases of the finest and purest manufactured leaf. The latest improvement in the art of adulteration detected by the Government analysts is due to the ingenuity of certain Scotch snuff manufacturers, whose "sneeshin" was found to be a mixture of snuff and alkaline salts, liberally coloured with *red oxide of* iron.

HIDES AND LEATHER.

By James Collins, F.B.S. Edinburgh, &c.

It has been well said that Nature clothed the lower animals and left man to clothe himself, and that the chief difference between the two is, that the latter borrows his clothes of the former. The subject of clothing is highly interesting, and has been made the medium of some curious remarks by a recent philosopher, who says, "The horse I ride has his own whole fell: strip him of the girths and flaps, and extraneous tags I have fastened round him, and the noble creature is his own sempster and weaver, and spinner; nay, his own bootmaker, jeweller, and man-milliner: he bounds free through the valleys with a perennial rain-proof court suit on his body, wherein warmth and easiness of fit have reached perfection; nay, the Graces also have been considered; and frills and fringes, with gay variety of colour, featly appended, and ever in the right place, are not wanting. While I, good Heaven! have thatched myself over with the dead fleeces of sheep, the bark of vegetables, the entrails of worms, the hides of oxen or seals, the fell of furred animals, and walk abroad a moving rag-screen, overheaped with shreds and tatters raked from the charnel-house of Nature, where they would have rotted, to rot on me more slowly!"

The earliest articles of dress that are mentioned were made of the skins (probably those of sacrificed animals) with which our first parents were clothed; and skins continued to be for a long period, and indeed still are amongst savage nations, the sole articles of dress. The hides or skins of animals in their fresh state are soft and flexible, but become hard and horny on drying, and much too rigid and brittle for use, beside being prone to putrefaction and decomposition under the influence of moisture; and man seems to have soon acquired the knowledge of preventing this putrefactive action, and of imparting to the skins, when dry, the suppleness found in them whilst fresh. Now this change is known as TANNING, and consists in the preparation of a material combining suppleness, tenacity, and a power of resisting moisture by inducing in the skin a chemical combination of the gelatinous tissue with some material of an astringent and mucilaginous character, or with suitable fatty matters. The skin so changed is called leather. This term is at once indicative of one of its characteristics, for the words leather, ledher, lydher, are derived from the Anglo-Saxon lith, lithe, lither; meaning pliant, flexible, easily bent; and the word lither is even used at times in irony or sport, implying one soft (in the brain) or supple (in the body). By leather, then, is understood the hide or skin of an animal changed by a process and prepared for use, by which it is preserved from putrefaction, rendered supple and tenacious, and comparatively impervious to water. Leather is very early spoken of in his-

tory, and beside its use as an article of clothing, was also employed for utensils and for thongs (before the introduction of cordage made of flax or hemp), and as a material on which to write. In the Bible we read of rams' skins dyed red, girdles made of leather, leathern bottles, and of Simon a "tanner." In ancient Egypt we find that leather dressing was carried to a high perfection, a special part of Thebes being allotted to curriers, who prepared the skins of the ox, horse, ass, sheep, and goat, and even wild animals, by the use of certain plants. Skins so treated were used for writing on, for shoes, sandals, saddlery, as coverings for chairs and sofas, for dagger and quiver sheaths, and for shields and helmets. The stamping and ornamentation of leather were also resorted to. Amongst the Grecians, prepared skins and leather were used for dresses, sandals, shoes, aprons, helmets, and shields, while shoemaking was recognized as a craft. Amongst the Romans, prepared skins and leather were largely used for coverings of couches, shoes, and saddlery, and were often highly and richly ornamented.

The employment of leather for defensive purposes gave way to metallic armour, but again came into use on its decline. The leather made from the wild bull, buffalo, ox, or urus, found in Poland, Hungary, and some parts of Russia, was long celebrated, as it was pistol-proof, and also turned the edge of the sword. The common name of the animal was *buffe*, hence our term buff leather; and in one of the early charters of the Russian Company, the importation of a certain

number of these hides for military purposes was rendered obligatory. The hide of the real Italian buffalo was also used for the same purposes. Modern buff leather, however, is made from cow hide, and is very different to the original. Amongst the Hungarians the method of preparing leather by tanning was early practised, and in 1584 it was introduced into Neufchatel, and in 1628 into France, from whence the Hungarian method spread into Germany. The Arabs and Moors have long been celebrated for their leather, and their peculiar kinds known as cordovan, morocco, and shagreen leathers, were early imitated and even surpassed; these being imitated in England as early as the end of the seventeenth century, while France early acquired a great degree of excellence in the preparation of the lighter and more ornamental kinds of leather.

Leather can be made of the skins of all animals, but those furnished by cattle and by horses are preferred. The quality of a hide depends much on the kind of food and mode of living of the animal; those of wild cattle being stronger and more compact than those of domesticated cattle; and those of stall-fed, better than meadow-fed or grazing cattle. The thickness of a hide varies on different parts of the body; that on the back and head being much thicker than other parts, and that on the belly being the thinnest. This difference of thickness is less conspicuous in the case of sheep, goats, and calves. In sheep the skin is thinner, as the wool is longer. The sources from whence we obtain skins and

hides are numerous, and as the extermination of wild animals in Europe lessened this means of supply, the skins from domesticated animals more than made up the loss. Geographical discovery, too, opened up new tracts, which have yielded large and lasting supplies of skins and hides. South and North America, from the quantity of wild cattle roaming over their plains, have been largely drawn on for supplies, and the Russians collect also great quantities of skins from the wild animals of Siberia. Our supplies are obtained from home and foreign sources, on which, previous to 1830, a duty was levied. The "green" or "fresh" hides are those furnished by butchers from animals killed for home consumption, and "dry," "salted," or "smoked" hides are those imported from foreign countries. Skins are greatly injured at times by swarms of hairy grubs (*Dermestes vulpinus*) which feed on them, and often a package on its arrival from a foreign port is found to be valueless through their attacks.

Though I have used the words "hides" and "skins" synonymously, yet there is a difference recognized between them. Hides are properly *thick* skins, thick hides being called "butts," whereas those only that are thin retain the name of "skins." Skins differ much in thickness; that, for instance, of the hippopotamus being 1 to 3 inches thick, those of the lamb and kid not equalling the thickness of ordinary pasteboard. The skins of bulls make thicker, coarser, and stronger leather than those of the cow, while that of

the bullock is intermediate between the two, and that of the calf is thinner than that of the cow.

Ox hides, the most valuable, are imported from the plains of South America, from the Cape of Good Hope, and from Morocco. The South American hides, which are in the highest repute, are obtained from the half-wild cattle which roam over the wide plains between Buenos Ayres and the Andes, and prepared for the market by being dried, smoked, or salted. The leather from these is used for soles of boots and shoes and for harness. Cow hides generally yield an inferior grained leather, those of South America being worked for light soles. Calves' hides are thinner than those of cows, but when well tanned, curried, and dressed, yield a very soft and pliable upper leather for boots and shoes. Nearly all the so-called kid tops of boots are not from the kid, but from the calf, and is technically known as "calf-kid."

Horse hides are not so fine in the grain as those of the ox, and are generally used for saddlery, or thongs for common whips, &c. In addition to the supply of the home market, large quantities of horse hides are imported from South America, in which country, previous to the visit of the Spaniards, horses were unknown, though now there are vast herds, the descendants of those first introduced from Spain. Sheep skins are among the most useful that we have, as by dressing they can be made to imitate almost any of the dearer kinds of light leather. They are generally tanned with bark, and sometimes split, the upper or grain side being used for bazils and various fancy leathers,

such as imitation morocco, roan, &c. Sometimes, however, they are tawed with alum and salt, for making white leather. The under or flesh side of a sheep skin is made into "skiver" or chamois-leather, better known as wash-leather, and at other times used in the production of parchment. Sheep skins, when fresh from the animal, have the wool taken off by a fellmonger, and in this state are called "pelts." Beside the quantity of skins supplied by the home market, we import largely from the Cape of Good Hope, the sheep of which have medium quality wool, and a large fatty tail. The skin, however, furnishes a leather nearly equal to morocco, and is often used for tan driving-gloves, being at once serviceable and durable. Lamb skins are tawed and sometimes split, the top or grain side being used as a white leather for laying over chemical bottles, and the flesh side made into a thin chamois for lining gloves. In Italy, the south of France, and Spain, it is the practice to kill lambs at a much earlier age than in England, and the skin is consequently thin, small, and fine, and is used as a substitute for kid, though it is not so strong or glossy. Turkey, Sicily, and Austria also furnish many lamb skins, and those of the vale of the Arno, in Italy, are in the highest repute. The skins of lambs which die a few days after birth, are employed for lining purposes, and a portion also for gloves. Goat skins have long been prized for the excellence of the leather which they yield. In Switzerland, the south of France, and Italy, great numbers of goats are reared for the sake of their milk, and their skins are exported to this

country to be prepared as true morocco leather. Goat skins, and especially those of Switzerland, have a beautiful grain, are easily dyed brilliantly and permanently, and are much stronger and more durable than sheep skins. The leather is largely in request for covering chairs, carriages, and books, though much of the morocco used for books, &c., is roan, or a sheep-skin imitation. The skin of the Cape of Good Hope goat is much thicker than any other, being as large at times as that of a fallow deer. In Germany it is made into dresses by the peasantry. The Mogadore goats have very long hair, which, after being shorn and curled, is used for stuffing chairs and mattresses. The skin is inferior, and is usually made into black Morocco or "black Spanish leather," so called from the circumstance that our first supplies of this variety was from Spain. East India goat skins are small, and chiefly employed for ladies' boots and for covering seats.

The South of France, Spain, Germany, Switzerland, Italy, and Ireland, produce large quantities of kid skins; those of France being the most perfect and of the finest quality. They are valued chiefly for the best kinds of gloves, the "kid" gloves of lower value being skins of other animals dressed to imitate the real "kid." East Indian kid skins are used for light shoes and gloves, though the "white kid boots" are mostly made of white sheep leather. Great care is taken in the rearing of kids, which are generally killed before they commence feeding on herbage, for as soon as they leave off their mothers' milk, the deli-

cacy and fineness of the skin is injured, and rendered unfit for glove making. Older kid skins are used for shoes, braces, and binding purposes, for which they are suitable from their great strength and elasticity. Deer skins are collected in large quantities in Canada and the United States, and are generally prepared with oil, or chamoyed. Some of these are imported, and, together with our home supplies, are manufactured into gloves, riding breeches, boots, braces, &c. The hair forms one of the best materials for stuffing saddles. Antelope skins are also imported from the Cape of Good Hope.

Pig or hog skin leather is principally valued by saddlers. The chief supplies are from Scotland; as in England and Ireland pork is generally cooked with the skin on. Skins of wild boars have been known to be of the thickness of two inches; and in the Exhibition of 1851 an even thicker skin was shown, which had taken seven years to tan. Much of the so-called pig skin is but an imitation, the skins of other animals being passed between plates or rollers with a number of projecting points, by which the peculiar punctated or dotted appearance of real pig skin is imitated. It is no uncommon thing for the upper side of the flap of a saddle to be of real pig skin, and the under of an imitation. Hippopotamus hides are occasionally imported from South Africa, and, when tanned with oak bark, are exceedingly thick and compact. Cat, dog, and rat skins are also made into leather, chiefly for gloves. The French are said to be very proficient in the preparation of rat-skin leather, large supplies of which

are obtained from the sewers. Leather prepared from the skins of sea mammalia, and particularly that from the seal, is very strong. The seal skins are much used as furs, but great numbers are obtained, for the sake of the leather, on the shores of Newfoundland and the Arctic Ocean. When young, the seal has long, white, silky hair, which in a few weeks is replaced by a coarser and darker kind, and this is the period when it is best adapted for leather. Seal-skin leather when carefully prepared has greater strength in proportion to its substance than any other kind, and has a very fine grain. The skin is split, and the grain side, when black enamelled, is largely used in ladies' boots and for binding, on account of its strength, even when very thin.

Let me now briefly notice the structure of skins, before proceeding to the consideration of the operations of tanning. The hide or skin of an animal may be said to consist of three parts. In the uppermost we find two layers: the first a thin, semi-transparent cellular layer, known as the epidermis, in which the hair is seated; the second, a more or less horny layer, called the "Malpighian," in which is contained the nerves, smaller blood vessels, and the base of the perspiratory glands. In the preparation of leather the first of these layers is removed with the hair, while the second forms the "grain" or "bloom," i.e. hair side, of the leather. The second or middle portion, known as the real *corium* or *derma*, is fibrous in its structure, and forms the leather. The third or undermost is a fat-bearing tissue, lying between the derma

and the muscles of the flesh; and this, too, has to be removed. Leather therefore consists of the corium portion of the skin, covered with the bloom or Malpighian stratum, from which, by cutting and scraping as well as by the action of lime, the other integuments have been removed. In some leathers this bloom is also removed, and is then called "buff." In split skins the under portion or chamois is of course without this bloom. All parts of the skin swell up by the action of hot water, and by prolonged boiling are converted into glue. Acetic acid changes the *derma* or fibrous portion into a jelly, although the jelly retains all the structure of the unchanged derma. Alkaline leys dissolve skin slowly. Lime and baryta-water dissolve the cellular tissue; and it is on the action of the lime that the preparation of the skin by steeping and dressing is founded, previous to the process of tanning. The derma or corium of the skin chemically combines with tannic acid several metallic oxides, e. g. alumina (tawing with alum and salt) and oxides of iron and chromium, with oxidized fatty matter, insoluble metallic soaps (compounds of stearic, palmitic, and other fatty acids, with oxides of lead, &c.) with picric and pinic acids. All these are tanning substances; that is, they possess the property of being precipitated on and chemically combining with the fibres of the corium, so that on drying they prevent agglutination, and preserve the natural suppleness and softness of the fresh skin. This operation then of tanning, as I have already stated, is a process by which the skins of various animals, especially those of the larger mammalia, are

changed into a tough, flexible material, resisting putrefaction, and not turning to glue when boiled in water (or, at all events, only after long-continued boiling), and not horny and brittle when dry, like simply dried skins. Its preservative action extends even to those working in it. The Gravedigger in "Hamlet" says, that the skin of a tanner gets so tanned with his trade, that it will keep out water a great while.

There are three methods used in the tanning of leather, viz.:

1. Tanning (strictly so called), by which the astringent principles of certain plants are made to combine with the hide; of this there are two kinds:
   a. Red-bark tanning, for thicker kinds of hides.
   b. Sumaching, similar in its results, but less laborious and tedious, and performed on thinner hides or skins, which are often subsequently dyed.
2. Tawing with alum and salt, with oil worked into the skin, resorted to in the preparation of white and black kid, principally for the glover.
3. Shamoying, sämian, or oil tawing, resorted to in the preparation of chamois or wash leather, by the combination of some suitable fatty matter with the texture of the corium divested of the "bloom" or Malpighian stratum.

These I shall notice individually.

1. The process of tanning depends on the action of an astringent principle, known as tannin, or tannic

acid, which is very extensively diffused throughout the vegetable kingdom. Barks and leaves of most forest trees possess it, more or less, as the oak, elm, horse-chestnut, pine, willow; the wood and bark of shrubs, as the shuma, acacia, &c. Tea and coffee also contain tannin. The acids, however, obtained from these various sources differ somewhat from each other, but all agree in having an astringent taste, with an acid reaction on test paper; giving with the salts of peroxide of iron a deep blue-black or green-black colour (clean ink); precipitating solutions of gelatine and converting animal skins into leather. This action on gelatine is one of the best tests of tannic acid, and by it the way in which leather is formed is well shown. If a solution containing tannic acid be poured into one of isinglass or gelatine, the latter becomes coagulated into a leather-like substance.

In the presence of alkaline liquids, such as lime water, caustic potash, or ammonia, if air be also present, tannic acid decomposes, and the importance of this fact will be at once seen when we treat of the use of lime in the cleansing of the skin, and the great necessity of every trace of it being removed before submitting the skin to the action of tannin, for if the lime be left, it would neutralize the action of tannic acid by decomposing it. There are four well-marked varieties of tannic acid, viz. gallotannic, found in galls; quercitannic, found in the oak (*Quercus*); moritannic, in fustic (*Morus tinctoria*); and mimotannic, in the catechu. Gallotannic acid is obtained in a state of purity from gall nuts, and also from sumach.

Oak galls contain about two-thirds of their weight of tannic acid, and 2 per cent. of gallic acid. To obtain the former they are reduced to powder, and an equal weight of washed ether added. The liquid separates into two portions, the denser of which is of a yellow colour, and which, when evaporated, yields a porous, pale buff-coloured residue, which is amorphous gallotannic acid. It is freely soluble in water, and reddens blue litmus paper, the latter change being a proof of its being an acid. It precipitates iron salts of a bluish-black colour, and ink is but a gallotannate of iron.

Mimotannic acid is a variety of tannin found in catechu and kino, and gives a greenish-grey colour when added to a solution of iron salts: it is freely soluble in cold water, and sparingly so in dilute sulphuric acid. Catechu consists of mimotannic acid and catechu, together with a brown substance resulting from the oxidation of these two. Catechu is not soluble in cold water, but is soluble in three or four parts of boiling water or boiling alcohol.

Oak bark is the most important of all the substances known to the tanner. Nothing has been found to equal it, and the superiority of English sole and other thick leathers is ascribed to its use. It is the inner bark of *Quercus rober*, *Quercus pedunculata*, and other oaks, stripped from the trees and branches at an age of nine to fifteen years, and when cut or ground up is called "tan." Beside home supplies, we get large quantities from Holland and Belgium, though foreign oak bark is not accounted so valuable as that of English oaks. The

percentage of tannic acid in the best barks has been stated by Büchner as not higher than 6 or 7 per cent. Wolff has, however, placed the figure much higher, as the following Table shows:

	Tannic Acid.	Age of the Trees.
	per cent.	years.
In the crude part covered with the rind	10·86	41 to 53
„ inside layer of the old bark ..	14·43	41 „ 53
„ inside of the bark	13·23	41 „ 53
„ crude bark and inside of bark	11·69	41 „ 53
„ inside layer and inside of bark	13·92	41 „ 53
„ inside of bark	13·95	14 „ 15
„ „	15·83	2 „ 7

The loss of percentage in the older bark as compared to the younger has been ascribed to a gradual change of the tannic into gallic acid. The tannic acid alone, however, has not been found to have an equal effect with the whole bark, as the mucilage and other constituents of the bark have also a beneficial action in the tanning. In France the bark of the evergreen oak is used, and to its employment the softness of French leather is ascribed.

Valonia is the dried acorn cup of the *Quercus ægilops*. It is often more than an inch in diameter, but is sometimes imported in a half-grown state, known as *cameta;* or younger still, just after it has flowered, and is then called *camatina*. The younger it is, the more valuable, and is chiefly imported from Smyrna, and said to contain from 40 to 45 per cent. of tannin.

Tanners' sumach, or sumac, the Moorish term for dye, is next to oak bark in importance. It consists of the flowers, leaves, and twigs of the *Rhus coriaria* and *Rhus typhina*, found wild in the south of Europe and the Levant, and cultivated in North America and Algeria. The root shoots are planted in June, and after three years the shrubs are large enough to admit of the branches and leaves being gathered. They are then cut off, dried in the sun, and threshed with a flail, though sometimes ground under millstones and sifted. The powder is of a blue-green or yellow colour, and contains from 12 to 16 per cent. of tannin; but by long keeping it deteriorates, as the tannin becomes changed by spontaneous fermentation. Beside the tannin, it also contains a yellow dye. Venetian or Italian sumach is the young twigs and leaves of the *Rhus cotinus* or *Ruga*, which grows near Vienna, and is largely used in tanning sheep and goat skins.

Fir bark (*Pinus sylvestris*) is one of the best tanning materials, and contains from 5 to 15 per cent. of tannin, about 7 per cent. being the average. The bark is stripped off the tree as soon as it is cut down, and is frequently used for tanning sole leather. The bark of the *Pinus Canadensis* is most used in the United States in the form of an extract, known as "hemlock extract," containing about 14 per cent. of tannin. Elm bark contains 3 to 4 per cent.; that of the horse-chestnut bark 2, and beech bark 2 per cent. of tannin, and are all more or less used.

The young branches and twigs of willow bark (*Salix caprœa* and *S. cinerea*) contain 3 to 5 per cent.

of tannin, and to its employment together with that of oil of birch, both cheap and abundant articles, the superior quality of Russian leather is ascribed. It is also well suited for tanning some kinds of glove leather.

Mimosa bark is obtained from the *Acacia melanoxylon*, *A. dealabak*, and other species; and is sometimes exported from Australia in the form of an extract, a very much cheaper way than sending the bark, as much freightage is saved. It is a valuable tanning material, but the imports have not been large.

Cutch, Catechu, and Gambier are three well-known tanning substances, and very useful for quick tanning. Cutch is an extract obtained by boiling in water the heart-wood of the *Acacia catechu*, a tree common throughout India. When thick, it is poured out on large leaves to dry, and appears in commerce in masses of a blackish-brown colour, shining, heavy, bitter, and powerfully astringent.

Gambir, Gambier, or Terra Japonica, is an extract obtained by boiling the leaves and young shoots of the *Uncaria gambir*. It occurs in cubes, brown externally, internally yellowish or brick-red, breaking with a dull earthy fracture. It has a bitter, very astringent, and mucilaginous taste. The plant is common throughout the Malayan Archipelago and Peninsula.

Betel nut, or *Areca catechu*, is an extract prepared from the well-known areca nuts, the seeds of an Indian palm (*Areca catechu*). It occurs in round flat cakes, from 2 to 3 inches in diameter and from ½ to 1½ inch

thick, has a blackish-brown colour internally, and a strongly astringent, rather bitter taste. The proportion of tannic acid (mimotannic acid) is very high in these three varieties, some giving a percentage of 50.

Kino is another extract from the wood of various trees, of which there are four varieties, viz.:

East Indian	Kino,	obtained from	*Pterocarpus marsupium.*
African	„	„	*P. erinaceus.*
„	„	„	*Butea frondosa.*
West Indian	„	„	*Coccoloba uvifera.*
Australian	„	„	*Eucalyptus resinifera*, &c.

Kino consists of small, angular, brittle, brown-red to black coloured masses, with a glassy fracture and brown-red powder. It is soluble in hot water and in alcohol, yielding a blood-red solution of an astringent and sweet taste, and contains 30 to 40 per cent. of tannin.

Divi-divi is the seed-pod of the *Cæsalpinia coriaria*, a native of the sea-side marshes of the Spanish Main, which has also been naturalized in India. The pods in drying become curiously curled like the letter S, and are of a brown-red, with polished seeds of an egg shape, and olive-green colour. They contain from 60 to 65 per cent. of tannin, and are much used, though very expensive.

Myrabolans, the fruit of *Terminalia chebula*, &c., a plant very common in some parts of India, has pods of about 1 to 1½ inch long, of an ovoid shape, somewhat tapering at the end, more or less deeply furrowed, and covered with a yellowish or dark-brown skin, underneath which is an astringent, hardened

pulp, enclosing a seed said to be narcotic. Besides tannin, it also contains a yellow dye.

Pomegranate bark, or rather the rind of the fruit of the pomegranate (*Punica granatum*), is occasionally used, and is said to be the chief material in tanning morocco leather.

Galls are too expensive for general use in tanning operations, and are more susceptible to fermentation and other changes by which the tannic acid is changed into gallic acid and glucose, the former being unfitted for tanning purposes. Several varieties of galls are known to commerce, such as oak galls, excrescences formed by the puncture and deposited ova of the oak wash (*Diplolepis Gallæ tinctoriæ* of Latrielle), an hymenopterous insect on the *Quercus tinctoria* of Olivier. They are hard, heavy, globular bodies, smooth on the surface, and with numerous tubercles having a small cavity in the centre which contains the larva of the insect. There are three varieties, black, green, and white, from the first and second of which the insect has not escaped, while the third is larger, and pierced from the centre to the outside by a small hole made by the insect to effect its departure. Large quantities of blue and green galls are imported from the Levant, galls of warmer countries, such as Aleppo, containing 58 to 60 per cent. of tannin, whilst English galls yield only from 5 to 6 per cent.

Chinese and Japanese galls were first imported about 1847, and are produced by puncture and deposited ova of an insect, the *Aphis linensis*, on the *Rhus succedanea*, *R. javanica*, and R. semialata, shrubs

which grow in Nepaul, Japan, and China. These galls are large, hollow, thin-walled excrescences, of an oblong bean shape, having a horny texture and conchoidal fracture, and covered with a yellowish-grey felt. They contain about 60 per cent. of tannic acid, and are chiefly used as a source of gallic acid.

Of these, as I have before stated, oak bark is held in the highest estimation, and as soon as the supply became insufficient, other substances were sought as substitutes. The sawdust of the oak, valonia, chestnut, willow and larch bark, ferns, myrtle, sumach, mastic, catechu, and many others, have been used. Each variety of these tanning substances imparts to leather a distinctive quality of colour, scent, capability of resisting moisture and decay, and often two or more substances are used together in order to obtain the combined qualities.

The operations in oak or red bark tanning are three, viz.:

a. Cleansing and dressing the hide on the hair and flesh side, or in other words, the separation of the corium from the other integuments.

b. True tanning.

c. Currying and dressing.

a. In cleansing the hide, there are four steps: 1, steeping and macerating; 2, dressing the flesh side; 3, dressing the hair side; and 4, swelling of the cleansed hide. The object of the steeping and macerating is to get rid of the blood and soil, and also salt and other materials used in preserving the hide. *In the case* of green or fresh hides, two to three days,

and in foreign hides eight to ten days, are consumed in this step. The hides are simply washed or soaked in a stream of water, and taken out and drained twice a day. When they have become sufficiently supple, they are removed, placed on a semicircular plank, called a "tree," and the flesh side is planed or shaved with a "dressing knife," consisting of a slightly curved knife fixed in a handle. After again soaking in water for about twenty-four hours the dressing is repeated, and by this means the fat and other integuments situated between the hide and muscles are removed, and the hides are then left to drain. To expedite the operation, they are passed through fulling mills and beaten with heavy hammers shod with iron, by which means they are rendered supple and clean, two or three days sufficing for this operation, whereas by manual labour eight or ten days are occupied. The next step is to remove the epidermis and hair containing integuments, and as they are firmly attached to the corium, this can only be done through a partial dissociation of the layers by the action of certain materials which cause the skin to swell up. This is effected by liming (the application of the compounds of sulphuret of calcium called "rusma"), or sweating. The hides are placed in pits containing milk of lime, there being generally three to five of these with solutions of different strengths, the hides being transferred from the weaker to the stronger during the three or four weeks in which they are under treatment. The liming not only prepares for the removal of the epidermis and hair, but also *saponifies* the fat contained in the hide,

and although lime-soap is insoluble in water, yet it can be removed by subsequent chemical and mechanical operations. In some of the French tanneries, a weak solution of caustic soda is used instead of lime, as it is more easily removed than an excess of lime. Very thin skins will not bear the action of liming without injury, and for this purpose the salve-like material called "rusma," consisting of one part of orpiment to three parts of slacked lime, is rubbed over the skin, which thus becomes so softened as to render the removal of the hair easy. Hydrosulphuret of lime has been found to answer well as a rusma, and for this purpose the lime from the gas purifiers has been used in treating hides as well as skins with good results. A semi-putrefactive fermentation is employed in the case of thick hides for sole leather; as, if placed in lime pits, their thickness would render the complete removal of the lime impossible, and thus decompose the tannin and make the leather brittle. The sweating is performed by rubbing the skins over with salt or crude wood vinegar, and placing them flesh side to flesh side in an air-tight tank or box, in which they commence to putrefy. When they give off ammonia they are removed, as the disengagement of this gas shows that the operation has proceeded far enough. At other times the skins are hung up in rooms heated by steam or a furnace, by which the skin becomes thoroughly softened. There is also a cold sweating process, in which the hides are placed in a box, and a constant stream of warm water passed over them.

As soon as the hides have become soft enough by

any of these processes for the removal of the hair and the integuments by which it is sheathed, they are transferred to a tree and dressed with a knife, the workman strewing fine sand in order to get a better grip. They are then washed and made of equal thickness throughout by planing or dressing, the ear, tail, and leg pieces being reserved for the glue manufacturer. By this operation the hides lose 10 to 20 per cent. of their weight. The next process is that of "raising" the hide, the object of which is to remove the lime and open the pores, so that the tanning materials may be more readily absorbed. This is done by using a "sour bath," consisting of refuse barley, rye, malt, or bran, which contain butyric, lactic, and other acids, and as the acid fermentation decomposes the lime-soap, the free acids float on the top, and the soluble lime salts are easily removed by washing with water. The mechanical action of the carbonic acid evolved from the carbonate of lime deposited in the hide, together with the gases from the fermentation of the acids of the sour bath, distend the hide to twice its original thickness. All hides, indeed, after sweating, will swell up if placed in water, but the use of the sour bath is preferred, as its action is much more regular. Other means are occasionally adopted to bring about the same effect. Sometimes the hide is immersed for about twelve hours in a bath, containing 1 part of sulphuric acid to 1000 of water; but although the action is quicker, great care has to be taken, as excess of acid or the too long subjection to its action injures it, and renders the leather brittle. Red tan liquor, a solution

of spent oak-bark, contains a large quantity of lactic and butyric acids, and is also used for "raising" the hides. Phosphates and excreta contain large quantities of uric acid, and excreta of dogs and pigeons are used for raising sheep, calf, and goat skins. The hide has thus been brought, by these preliminary operations of cleansing and removing the portions not required, into a fit state to receive and absorb the liquor in which the tanning matter is dissolved.

Tanning.—The next step is to place the hides in a very weak infusion of bark, called *ooze*. This is pumped into rectangular pits, 6 or 8 feet deep, sunk into the ground, lined with wooden planking, termed *handlers*, because the hides are daily transferred from one pit to another of greater strength, an operation that takes about six weeks. The necessity of employing very weak solutions of tannin is at once apparent, when it is remembered that if a strong one were used, the outside of the hide would become so thoroughly tanned as to prevent it from acting on the inside. The next step, that of subjecting the hides to an increased action of the tannin, is performed in various methods, by placing the hides in tanks or *layer* pits with oak bark and water, by immersion in a liquor made of the tanning materials, or by certain quicker methods. At the present time, tanning in the bark is confined to heavy hides for sole leather. The tanks are sunk into the ground and are generally made of oak or fir planks, for if they are of brick, and especially when newly built, the lime in the mortar acts on the tannic acid. In Germany they are made *of slabs of slate* or sandstone. Each tank holds from

fifty to sixty hides. On the bottom is laid a layer of spent tan (i. e. ground bark or tan which has been already used), then a layer of fresh ground oak-bark, surrounded by hides and bark alternately, till the tank is nearly filled, the thicker parts of the hide having more bark and the interstices filled up, while the whole is covered over with a layer of spent bark 12 inches thick. Water is then poured in till the uppermost hide is covered, and a lid or loose plank is then placed over all. The first tank contains a strong solution of about 80 lb. of bark, the second 70 lb., and the third 60 lb. When valonia, catechu, or other substances are used, a less quantity of oak bark is required. The hides are left in the first tank for about eight to ten weeks, and before all the tannic acid has been absorbed and the formation of butyric and other acids commenced, they are transferred to the second, where they are allowed to remain for three or four months, and thence into the third tank, where they remain for four or five more. In making these changes the hides are placed in reverse order, so that those at the bottom in the first tank are at the top in the second, as otherwise the hides would be unequally tanned, on account of the liquid at the bottom being densest, and therefore strongest. Very thick and heavy hides take a longer time. Three hundred lb. of oak bark tans 100 lb. of fresh skins, which when tanned weigh about 150 lb. Thinner hides and nearly all skins are tanned in liquor which is an infusion of the tanning material contained in tanks of different strengths; and the hides, before being transferred from a weaker to a *stronger liquor,* are thoroughly pressed, in order to

get rid of the weaker liquid. Thin hides or skins are tanned in seven or eight weeks, thicker ones in eleven or twelve weeks.

The length of time required has led to numerous methods, some indeed very irrational, whereby the process could be shortened. One method recommended was to force the tanning liquid through the hides by hydrostatic or hydraulic pressure; another, to fix the hides on a sort of paddle-wheel, and, by revolving it, alternately raise the hides out of and plunge them into the tanning liquid. It was also proposed to puncture the hide with fine needles. Stronger oozes have been used, but, as I have already stated, the outside of the hide becomes so completely tanned that the inside is not touched. But none of the methods of quick tanning are in very general use, as it is found to make the leather harsher, less supple and durable. When the leather is perfectly cured, it does not show any white streak in the centre, but is of an uniform brown colour throughout.

When the leather is thus completely tanned, it is removed to a drying loft, heated in damp weather with steam-pipes, and, when sufficiently dry, is beaten on a cylindrical beam, and subsequently rolled with a brass roller, loaded with a weight of from 10 to 12 cwt., or passed through the cylinders of a machine. The leather is thus made more solid and supple, and it is finally dried in an airy building and stored for sale. Here properly ends the province of the tanner, the subsequent dressing and currying of the leather, though often combined, being, strictly speaking, the trade of

the currier. When the leather is simply tanned, it is not fit for use, and has to be dressed in order to impart to it compactness of texture, better grain and appearance, softness, toughness, suppleness, and colour. The operations differ according to the purposes to which it is to be applied; leather intended for soles being subjected to hammering on a polished stone slab, with wooden or iron hammers, either by hand or machinery.

Leather required for the uppers of boots and shoes, saddlery, &c., has to pass through the more complicated process of currying or impregnation with oil. It is first soaked in water, then stretched, hair-side downwards, upon a beam and shaved with a flat-bladed knife, with a handle at each end. The hide is thus pared or whitened and the inequalities removed. The "grain" of the leather in drying becomes flat, smooth, and unequal, and if it be desired to "bring it out," it is subjected to the graining operation. For this purpose a pommel, graining, or crimping board, as it is variously called, is used. This is a piece of board about 12 inches long and 5 or 6 inches broad, flat on top and somewhat curved at bottom, across which are cut in the direction of its width a number of parallel notches. The leather, being placed on the dressing table, is then rubbed with the graining board, the result of which is to raise the natural grain. Instead of notches the board may be covered with vulcanized caoutchouc, which offers sufficient "grip" or resistance to the leather to prevent its gliding over the surface. Where no grain is left on the leather, it is rubbed with pumice-stone to render *it smooth*. If a polished surface is

desired it is rubbed with a cork pommel, or to obtain still greater brightness, with iron or copper "slickers," followed by others of cylindrically shaped glass. The slicking tool used in England is a very simple and effectual instrument. It consists of alternate plates of steel, stone, and glass with a rounded edge, to which an oval piece of wood, about 8 inches long, serves as a common handle. By means of these tools the inequalities are removed, the leather cleaned and polished, being finally finished off and smoothed with a flattening iron. When it is required to be supple, such as for upper-leathers, it is dubbed with a mixture of cod-fish oil and tallow while still wet and hung up to dry, the oil taking the place of the water as the latter evaporates. It is then grained, scraped, or whitened on the flesh side and stowed away. It is next rubbed with a coat of tallow and one of size, and finally dressed with a paste containing fish-oil, tallow, lampblack, yellow wax, soap, and copperas, in order to preserve it from the injurious effects of sulphuric acid which is frequently contained in blacking. Ladies' boots are blackened on the grain side by being rubbed over with a solution of copperas, which, combining with the gallic acid of the tan, produces an inky stain or dye.

Russian leather has long been celebrated as very strong and water-tight, and was formerly made exclusively in Russia, where indeed large quantities are still prepared. This leather is usually called "yufts," a term supposed to be derived from jufti, a pair, as in the preparation they were formerly sewn together in

pairs. It is generally of a red or black colour, and is prepared from hides of young cattle, as well as from the hides and skins of horses, sheep, goats, and calves. The hides are first cleansed and unhaired, by means of lime as usual, and are then "raised" or caused to swell, by being placed in an acid bath, prepared with malt, spent tan-liquor, or with excreta of dogs rubbed up with water. They are next tanned with bark of the willow, and sometimes with fir and birch, being first placed for some days in weak solutions of partly exhausted bark, followed by stronger ones. This part of the operation takes five or six weeks. The hides are then placed on a planing block to drain, and are impregnated with oil of birch, obtained by dry distillation of birchwood. This oil contains creosote, phenol, or carbolic acid of a peculiar kind, and paraffin; and its application is continued till the hide is soft and supple, when the hair side is treated with a solution of alum, and then grained and the hide dried. The colour is imparted to them by sewing together in the form of a sack, and pouring in the dye decoction, or by brushing over five or six times with the dyeing material. The leather is then dressed in the usual method. The peculiar excellence of Russia is said to be due to the employment of willow bark and oil of birch, the latter effectually preventing the attacks of insects, which leads to its wide employment in bookbinding.

Morocco leather has been known for a long period, being first made by the Saracens, and even now by their descendants in Northern Africa and the Levant. Genuine morocco leather from skins of the Barbary

goat is soft, elastic, and retains a highly coloured surface. Much imitation morocco is now made by splitting sheep, calf, and other skins; and indeed some roans made from sheep skins have so great a resemblance to real morocco, that it takes a practised eye to observe the difference. The skins are first subjected to a very careful cleansing and raising. After washing and liming in the usual manner, they are then "raised" by an *abating* process, by being placed in a weak solution of ammoniacal salt (that of dog's dung being preferred), and when thus rendered soft and porous, are cleansed and sewed up into the form of a bag, into which a strong solution of sumach is poured. The bags, being full distended with this solution and with air, are then placed in a tub of a weaker solution, in which they are kept in motion for some hours. They are next piled one upon another upon shelves, by which mutual pressure the sumach is forced through the whole of the skin, the seams being kept closed. This is repeated with a stronger solution of sumach. In about three days the tanning is said to be completed. The dyeing of morocco leather is not always done in Oriental countries, and the tanned skins are frequently exported to Europe, under the name of Mechin leather, to be dyed and dressed. In dyeing genuine morocco, a dye vat (a small trough filled with warm dye-liquor) is used, but in the imitation the colour is simply brushed over. To produce a light-blue colour a mixture of yellow prussiate of potash and nitrate of silver is used; a maroon is produced by archil and ammonia with indigo; a scarlet, by cochi-

neal, alum, and carbonate of potash; and a rich or "royal" purple, by indigo faced with cochineal.

Imitation morocco is coloured with a brush and then dressed by rubbing over the hair side with linseed oil, glazed or cullendered by machinery, and finally "grained" by cylinders. Aniline dyes are now largely used in imparting brilliant colours to leather. Cordovan, or Cordwain, is another old variety of morocco leather. Chaucer speaks of "Buckskins of costliest cordovan." Caxton, too, in his 'Boke for Travellers,' speaks of "hydes of kyen whereof men make lether; of fellis of gheet, or of the bukke men make good Cordewan; of shepes fellis may be made the basenne." Cordwainer, or its old English representative "Cordiner," is a worker in cordwain or cordovan: a shoemaker therefore is a very old trade and guild in London. Cordwain differs from morocco in being prepared from heavier skins, and in having a "natural" and not a "platted" grain. It is usually dyed of a yellow, red, or black colour, and oil is used in its dressing.

Japanned or "patent" leather and enamelled leather are largely used for coach work, boots, shoes, helmets and military accoutrements, and if properly prepared resists water and does not crack or peel off, and is soft and supple. Enamelled leather, such as is used for bags, has the enamel laid on on the grain side and the grain preserved; in the "patent" leather, the varnish is put on the flesh side, and in the double patent, on both sides. To prepare it, a varnishing fluid is spread uniformly over the leather, which is then placed in a brick oven kept at a moderate heat, and baked. This

operation is repeated several times. The varnish is generally made with boiled linseed oil mixed with vegetable black and Prussian blue. Danish leather is tanned with willow bark, and has great strength and suppleness, which makes it specially useful for gloves.

Pianoforte leather (employed to deaden the too great vibration in pianoforte wires) is very carefully prepared, as it must be soft and elastic. It is partly tawed and partly tanned, after being successively fulled in oil, washed in ley, bleached in the sun, and finally tawed in tepid oak-bark solution. As a rule, foreign leathers, especially heavy kinds, are not so compact and well prepared as English leather, being much more spongy and absorbent.

Tawing.—This method of preparing leather from thin and delicate skins is based on the action of salts of alumina or gelatine. The common tawing method is by alum and salt alone, and this is used for thin skins, such as those of the sheep and goat. The pelts (so called if there be any wool on the skins) are first cleansed and planed as in the preparation of hides for tanning; then dressed on both sides with a dressing knife, anointed on the flesh side for a few days with a cream of lime, and the wool or hair carefully removed. In tawing, a "white bath" is used, consisting of 12 to 18 lb. of alum with $2\frac{1}{2}$ to 3 lb. of salt in twelve gallons of water for every hundred skins, the temperature being gradually raised to near boiling point. The action of the alum and salt is not clearly understood, but the tawing is generally attributed to the alum, the

salt only removing water from the fibres and preventing them from becoming glued together.

The presence of salt can always be detected by the damp feel of the leather in wet weather, its hygroscopic character causing it to absorb all possible moisture. After soaking in the alum bath, the skins are taken out and placed in revolving drums and well washed with water; their suppleness and flexibility is restored by machinery, and the white grain leather sold as "white sheep" for boot and hat lining. If the skin is thick, the upper or grain side is prepared as a "white" skin, and the under "flesh side" is shamoyed as wash-leather. The Hungarian method of tawing, now so long known, is employed for the preparation of leather from the heavy hides of oxen, buffaloes, cows, horses, &c. They are washed, shaved, and placed in a salt and alum bath, where they are frequently trodden by the workmen. They are next "fatted," by being held over a charcoal fire, and repeatedly rubbed over both sides with hot tallow, and then hung up to dry: the result being a cheap but strong leather used for saddlery, especially for artillery horses. The preparation of glove leather by the French, or Erlanger, method is one requiring much care and skill; all the materials employed must be perfectly clean and pure, even to the use of distilled water, as if the leather becomes spotted it is useless for white "kid" at least, or for delicate-coloured gloves. Ball-room "kid" shoes are made of "calf-kid," hides of young calves; the best kind of gloves, of the skins of milk-fed kids; and the second quality, of lamb-skin. After clean-

sing the skins in the usual manner, but with greater care, they are placed in a paste consisting of the best wheaten flour, yolks of eggs, alum, common salt and water, which, whilst it taws them, at the same time renders them soft and supple by the oil that it contains. In this mixture the skins are thoroughly soaked and kneaded, placed in heaps (2 or 3 per cent. of carbolic acid being added to prevent too strong heating), stretched by hand, and dried quickly by exposure to the air. They are then trodden by the feet, linen cloths being interposed, or they are placed in a revolving drum and again dried. After repeated washing, stretching, and planing, they are rubbed with a disk of glass ("a slicker"), and a solution of white of egg, gum, or fine soap, to give a gloss, and the leather is dyed on the hair side by being brushed over with a solution of the dye.

Knapp mentions that a very soft and white kid, with a beautiful gloss, can be obtained by tawing the epidermis of lamb or goat skins in a solution of stearic acid in alcohol. Several methods of tawing or tanning with mineral substances have also been recommended, but have not yielded a good leather.

Samian or oil tawing, known also as shamoying, is a process by which the skins and hides of oxen, sheep, deer, harts, and calves are converted into white, buff, oil, or wash leather. The name "shammy" is derived from the chamois (*Rupi capra Tragus*), which inhabits the Pyrenees and Alps and some of the higher mountains in Greece. The leather is used for military purposes, also as socks, braces, waistcoats, belts, for

surgical instruments, and for washing glass and polishing jewellery.

The preparation of shamoyed leather from sheep, goat, and deer skins was once a lucrative trade, great numbers of riding breeches being made for the cavalry of England, Prussia, Austria, &c. The Duke of Wellington, whilst in the Peninsula, substituted woollen cloth instead of leather, as the latter shrunk, was long in drying, and chilled the men, often producing rheumatism.

Sheep and other skins with the wool on are made into mats and rugs by the fellmonger, an ancient calling, meaning one who deals in fells or sheep skins. In Exodus we read of "ram skins dyed red." The grease is first removed, the skin is then made into leather with alum and sumach, or a weak solution of terra japonica, and the wool afterwards dyed with a permanent and bright colour. The coarse wool skins of Leicestershire and Lincolnshire sheep, and those of Angola are generally used for this purpose.

Some of the applications of leather I have already mentioned, and it would be needless and useless to attempt to enumerate them, as they are so well known. In its importance leather stands next to cotton and wool, and nearly if not quite equal to that of iron. Chemistry has made some improvements, but not nearly so many as in our other manufactures. Machinery has done much during the last fifty or sixty years, such as hydraulic presses for expressing grease, washing, glazing, and finishing machines. But the most important of these is the "splitting machine." The demand for thin

leather is immense, and such is the value of this machine that it splits a sheep-skin in three, allowing the top or grain to be used as skiver, or white leather; the second, as vellum and parchment; and the third, or flesh side, as glue.

The machine consists of two rollers, the lower one of solid gun-metal and the upper one of rings of the same material. These rollers revolve in different directions, and between them is a knife which moves backwards and forwards more than a thousand times in a minute. The skin, with the smooth side downwards, is placed on the lower roller, and is caught up and dragged forward to the knife, the rings of the upper roller adjusting themselves to any inequalities in the skin. The processes for beautifying leather by compression and polishing also render the leather so treated more solid and impervious to water. Stamped or embossed leather, which was revived in Paris about 1836, with many improvements, is a very durable and elegant covering for chairs, couches, balls, &c.; and by hydraulic pressure an impression from a mould is soon given to leather, the "relief" of which can be filled in with composition if need be. Dyeing, varnishing, and enamelling leather, have been carried to a high state of excellence, the employment of aniline and other brilliant and permanent colours, and the use of improved varnishes, leaving very little to be desired.

GUTTAPERCHA.

By James Collins, F.B.S., Edinburgh, &c.

The substance (or substances) known to us under the name of Guttapercha, is the concreted or inspissated juice of certain plants belonging to the natural order *Sapotaceæ*, growing in the Malayan Archipelago. The name guttapercha must now be looked upon as a generic one, but it was first applied to the product of *Isonandra gutta* (Hooker), which tree is looked upon as the guttapercha tree, though its produce is more correctly known as "gutta taban" or "tuban." The meaning of guttapercha is gutta (Malay) = gum and percha, the native name of the tree yielding this gum, the *ch* in *percha* being pronounced soft as in *perch*, and not as if spelt *perka*. The native name for the Island of Sumatra is Polu (i. e. Island) Percha, and is believed to have arisen from the fact of guttapercha trees growing there. The naming of a country from some product is not uncommon, as is known to be the case with the Island of Pinang, "Polu Pinang" meaning Areca Island, so called from the growth on it of the palm yielding Pinang or Areca nuts.

Of the early history of guttapercha very little is recorded. It was used by the Chinese from an early

period for various purposes, and its first introduction into England is generally ascribed to Dr. Montgomerie, though a sample or samples existed long before in the possession of the well-known family of the Tradescants. In the catalogue of their Museum, entitled "Museum Tradescantianum: or a Collection of Rarities preserved at South Lambeth, neer London, by John Tradescant," London, 1656, we have the following interesting entry:—

"VIII. Variety of Rarities.—*The plyable mazer wood, being warmed in water, will work to ony form.*"

I have italicised this sentence because it is so remarkable. The term "mazer" variously spelt appears frequently in old domestic catalogues and in poetry, it being applied to cups originally made of the maple or mazer, though afterwards applied to those made of other substances. These were often richly ornamented with carvings and quaint legends; and to these pledge cups or wassail bowls our forefathers were much attached, and often specialized them in their wills. Spencer, in his 'Shephearde's Calendear,' has the following:

"Then loe, Perigot, the pledge which I plight,
A mazer ywrought of the maple warre,
Whereon is enchased many a fayre sight,
Of beres and tygres that maken fiers warre;
And over them spred a goodly wild vine
Entrailed with a wonton yvie twine."

And again, in his 'Faerie Queene' speaking of Genius, he says:

". . . . . and by his side
A mighty mazer bowle of wine was sett,
As if it had to him bene sacrifide,
Wherewith all new-come guests he gratyfide:
So he did eke Sir Guyon passing by;
But he his ydle curtesie defide
And overthrew his bowle disdainfully."

Now this name applied to guttapercha may have been given either because cups were made of it, as a substance well adapted to bear injuries received in drunken bouts, or from the resemblance which it had to mazer or maple wood. Tradescant's "Closet of Natural Rarities" was by a deed of gift bequeathed to Elias Ashmole, and placed in the Ashmolean Museum at Oxford, but very few of the original specimens now exist, and up to the present time I have not been able to trace this specimen or its history. Another fact is worth recording, namely that one of the English vernacular names for the *Isonandra gutta* is "Mazer-wood tree." However, the further following out of this question is of too antiquarian a character to be dealt with in the present volume.

The honour of introducing this substance into European commerce is, as usual, claimed by more than one person, though it belongs to Dr. Wm. Montgomerie. In 1822, this gentleman was on duty at Singapore as assistant surgeon to the Residency, and whilst making inquiries relative to caoutchouc, was informed by the Malays of substances called guttapercha, guttatuban, and guttagirek. Having to leave Singapore and return to the Bengal Presidency, he was unable to follow up the subject till he was again stationed at

Singapore in 1842. He then noticed in the hands of a Malayan woodsman a *parang*, or axe, the handle of which was made of a substance quite new to him. He found on inquiry that it was of *guttapercha*, which he was told could be moulded into any form by simply dipping in boiling water until it became soft and plastic, and would regain its rigidity and maintain its form when it became cold. He obtained samples, and made several experiments as to its capability for surgical implements, and the results he communicated, with specimens, to the Medical Board at Calcutta; so strongly recommending its adoption, that the Board approved of his views.

In the same year he also sent specimens to the Society of Arts of London, which presented him with their Gold Medal for this good service. The merit of this introduction was also claimed by Dr. Jose d'Almeida, who, observing that this substance was used for native whips, sent specimens to the Royal Asiatic Society of London, which placed them in their Museum in April, 1843, but took no further notice. Curiously enough, the French also claim the honour, guttapercha having been obtained from Macao traders by a committee sent out to open up commercial relations with China (1830–1843), but by the time these were brought to France, patents had been taken out in England. From a careful comparison of the relative claims of Dr. Montgomerie and M. Jose d'Almeida, the priority in point of time and in publication seems clearly due to Dr. Montgomerie.

It was not, however, till 1847 that a name was given

to the tree which yielded guttapercha or gutta taban. This was found out by Mr. Thomas Lobb, who had been collecting plants for Mr. Veitch of Exeter in the Malayan Islands, and who, together with Dr. Oxley, sent specimens to Sir William Hooker, who described and figured the plant under the name of *Isonandra gutta*.

In 1856 Dr. De Vriese published the first part of his description of plants collected by Dr. Reinwardt, who had been employed for some years previously on a botanical mission for the Dutch Government in Malay, one of the results of the mission being the discovery of no less than eighteen trees yielding guttapercha. These trees consisted of an oblong-leafed variety of *Isonandra* gutta, as well as other species of *Isonandra*, *Sideroxylon*, *Chrysophyllum*, *Bassia*, &c.

Mr. Motley, an intrepid Englishman, who was massacred at Bangermassing in Borneo, paid great attention to the subject of guttapercha, as evinced by his specimens and remarks forwarded to the late Sir William Hooker, and the substance of some of these remarks I now give. *Isonandra macrophylla* of De Vriese, and called *Ngiato putih*, or white guttapercha by the natives, is a large tree, and yields a white or second quality of guttapercha.

The gum of *Mottleyana* of De Vriese is used to adulterate the inferior kinds of guttapercha, and is unsaleable by itself. Its seeds yield by expression an oil used for lamps, and when fresh, for cooking. The tree grows in deep bogs, and is called "kotian" by the natives. The *Isonandra dasyphylla* of Miguel also yields a very poor guttapercha and of very little

use. Another variety, called *Ngiato mevah*, or red guttapercha, yields a good quality.

I will now give a synopsis of the various substances known as guttapercha, for the purpose of distinguishing them, and I trust that it may induce those who have the opportunity to add to them.

Native Names.	Botanical Source.
Ngiato putih (i. e. white guttapercha).	*Isonandra macrophylla*, De Vriese.
Kolian	*I. motleyana*, De Vriese.
Benyon	*I. dasyphylla*, Miguel.
Ngiato mevah (i. e. red guttapercha).	*I.* species.
Guttapercha	*I. gutta*, Hooker, the same name being applied to other species generally. The *true* guttapercha is said to be an inferior article.
Gutta taban, or tuban ..	*I. gutta*, Hooker. This is said to be the correct native name of the product of this tree.
Gutta muntah, gutta soondie, gutta girek, or geggrek.	These are said to be synonyms of gutta taban, and also to be the produce of the same tree.

Gutta claison, gutta jelotong, gutta litchu, are also names of varieties of guttapercha.

Of these varieties I have myself met with parcels in English commerce under the following names: guttapercha, gutta taban, gutta muntah, gutta soondie, gutta girek, and gutta claison. Sometimes gutta muntah is sold as such, but as a rule only the term guttapercha is used.

The trees furnishing guttapercha are found on the alluvial tracts at the foot of the hills, where they *flourish* luxuriantly, forming in many spots the prin-

cipal parts of the jungles. They may be said to range over a square tract extending from 6° to 10° N. long. to 10° S. long., and from 100° to 120° E. long., and though found formerly in great abundance in Singapore, are now collected in Johore and along the Malayan Peninsula as far as Penang, and in Sumatra, Borneo, Java, Madura, and most probably throughout the numerous islands around. The accounts given of the collection of this substance are very interesting. The Tuban tree has a perfectly straight trunk of from 60 to 80 feet high, and 2 to 3 feet in diameter, when fully grown. Its wood is soft, fibrous, and spongy, of a pale colour, and marked by black lines consisting of reservoirs filled with the gum. The average yield of gutta at different seasons of the year is probably the same, but the collection of it is chiefly carried on in the dry season, as during the periodic rains, work in the forests is attended with fever, and the rain washes away the gutta as it exudes. The maximum yield of a full-grown tree is stated to be about 14 lb., but it is often much under that figure. The original mode of collection was by cutting the tree down in order to extract the gutta, and then ringing it with an axe at intervals of 3 to 18 inches, cocoanut shells, spathes of palms, or other receptacles being placed underneath to collect the milk. The contents of these were poured into a bamboo, and if the quantity was small, it was consolidated in the hand, and if large, carried to the huts and boiled to drive off the water. When quite pure, guttapercha is of a greyish-white, its reddish hue arising partly from the presence of an acid, but principally

from admixture with bark. When the first demand for guttapercha arose in 1845, trees were cut down wholesale in Singapore till the supply fell short in 1847, and ten years later guttapercha trees could only be seen as curiosities, and then only as young trees in gardens. The falling off in Singapore caused a general ransacking of the forests, so that native rulers soon claimed the collection as a monopoly, and became fully alive to their right of confiscating all that was collected by others in their territories. The exports from Singapore in these early years have been given as follows: In 1844, 1 picul (= 133⅓ lb.); 1845, 169; 1846, 5364; and in 1847, 9296: all collected in Singapore, Malay Peninsula, Johore, Sumatra, and Borneo. It has been calculated that to obtain a picul (133⅓ lb.) ten trees have to be destroyed, and as the quantity from the 1st of January, 1845, to the beginning of 1847 was 6219 piculs, no less than 62,190 had to be destroyed in order to furnish this quantity. In 1857 the export was about 4¼ millions of pounds weight, and the present estimated annual export is put down as about 10 millions. Singapore in this, as in the case of many other products, is the entrepot, and guttapercha is brought from the surrounding countries in large or small quantities, the low qualities of which are subjected to boilings. Its appearance before being boiled resembles shreds of a dry, ragged bark, light in colour, and easily crumbled by the fingers. The various parcels of guttas are sorted by Chinese as a rule, who bring great skill to bear in the operation. The parcels are boiled in an iron pan with cocoanut oil, and kept con-

stantly stirred, and re-boiled three or four times with fresh oil, till, with the addition of some portion of good gutta, the whole is amalgamated into a good-looking guttapercha, though much better in appearance than in quality. The best, however, is not so treated. In the English market guttapercha of three kinds is recognized, viz.: "*genuine*, re-boiled," and gutta muntah. The "genuine" is fine native guttapercha in pieces of irregular shapes and various sizes, of a pinkish colour, hard and tough in texture, and mixed with bark and other matters more or less. The second or boiled variety is generally in the moulded form of oblong slabs, and consisting, as I have mentioned, of various qualities, often of other guttas, boiled together to produce an even-looking substance. The third is porous, and of a white or greyish colour, and is believed to be crude guttapercha, which has not been subjected to any boiling or other operation whatever. In Holland there are no less than eight varieties into which guttapercha is classified in the public sales, the prices between them varying as much at times as 50 per cent. Letters are used to distinguish these classes, as A, AA, B, BB, C, CC, D, and Offal. Thus, in a series of specimens from Amsterdam, I have the following:

"A, splendidly fine and pure."
"AA, very fine and pure."
"B, fine, less pure."
"BB, good quality, very coarse, with much bark and wood."
"Offal, re-boiled, adulterated, very inferior quality, almost worthless."

The prices of guttapercha vary much, according to the supply and demand. Thus in January, 1873, we have prices quoted as follows:

	s.	*d.*	*s.*	*d.*	
Genuine, pure, dry, and unadulterated,	2	6 to	3	8	per lb.
Middling and fair	1	4 „	2	2	„
Common and re-boiled	0	9 „	1	3	„

These prices are much in advance of what they formerly were.

As I have already stated, guttapercha, when quite pure, is of a greyish-white colour, but, as met with in commerce, is of a red or yellowish hue. In this state it is nearly as hard as wood, only just receiving the impression of the nail, of a porous structure, and when viewed under the microscope has an appearance which has been compared to ice, consisting as it does of a series of variously hued prisms. When moulded, rolled into sheets, or drawn into ropes, it assumes a fibrous character in the direction of its greatest length, and this tenacity in a determined direction allows of stretching, though if stretched in the opposite direction it ruptures. If, however, a strip of a sheet be cut off, across the fibre, it will be found that in such a strip there is a redistribution of the tenacity; that is to say, the direction of the fibrous character is developed in an opposite direction. The electrical properties of guttapercha were first noticed by Faraday. If a piece be subjected to a gentle friction, an electrical spark can be obtained by its means.

At a temperature of from 32° to 77° Fahr., the tenacity of guttapercha is about equal to thick leather, though

it is less flexible and not at all elastic. At a higher temperature, viz. at 110° Fahr., it becomes in a water-bath less hard, and towards 120° Fahr. it softens and becomes doughy, though still tough; at a still higher temperature, from 145° to 150° Fahr., it becomes soft and pliant, readily allowing of being moulded and rolled. In this state it has all the elasticity of caoutchouc, but this it loses as it cools, and gradually becomes hard and rigid again, retaining any form impressed on it whilst in its plastic state. It contracts slightly in hot water. It is highly inflammable, and burns with a bright flame, dropping a black residue like sealingwax, which it much resembles. Dr. Adriani determined by a series of very accurate experiments the permanent stretching and elasticity of guttapercha. He employed a piece of machine belting, fixing one end and weighting the other, and observed by means of a delicate instrument the stretching whilst weighted and the contraction due to inherent elasticity, carefully regulating the temperature and time of each experiment. From these experiments it appears that the elastic stretching for a weight of 3 kilomètres is 0·00308 mètres, the permanent stretching being 0·0005 mètres. The band employed was 0·001775 mètres thick and 0·06 mètre wide, and broke with a weight of 106 kilomètres. In some experiments by Dr. Glover as to its capability of bearing pressure, it was found that a piece of piping 1000 feet long, having an internal diameter of 1 inch and an external diameter of $1\frac{3}{16}$ inch, bore a pressure of 100 lb. on the square inch without bursting, pieces of the same pipe

bursting only at 272 lb. on the square inch, while a piece $\frac{1}{4}$ inch internal diameter and $\frac{5}{8}$ inch external diameter burst only at 700 lb. on the square inch. The specific gravity of guttapercha has been variously stated from 0·96285 to 0·99923, M. Payen doubting whether it was lighter than water; and pieces when deprived of air (which its porous character easily admits) were found to fall to the bottom of a vessel of water.

Guttapercha, like caoutchouc, is a hydrocarbon, and both are by some even considered identical. The analyses given of guttapercha are carbon 87·80, hydrogen 12·20, by Soubeiran; carbon 87·22, and hydrogen 12·04, by Dr. Miller; while Faraday's formula for caoutchouc is carbon 87·2, hydrogen 12·8; and thus it is seen that the two substances are very near to each other. Commercial guttapercha is not a pure proximate vegetable principle, but consists chiefly of a hydrocarbon, which may be termed *pure gutta*, or simply *gutta*, and a soft resin mixed with it in about the proportion of 15 per cent.

The following is M. Payen's analysis of commercial guttapercha:

	Per Cent.
Pure gutta (milk-white in colour and fusible)	75 to 82
Resins, soluble in boiling alcohol, and consisting of two parts:	
1. Crystalbine or albane ($C_{20}H_{32}O_2$), a white crystallized resin, crystallizing out of the alcohol as it cools	16 „ 14
2. Fluavile ($C_{20}H_{32}O$), a yellow amorphous resin, falling as an amorphous powder on the cooling of the hot alcohol in which it is soluble	6 „ 14

Now the presence of this resin, which gives also colour to the guttapercha, is owing to the absorption of oxygen, and the consideration of the effect of atmospheric oxygen is very important in an industrial point of view, as the alternate exposure to moisture and dryness, and at the same time of the sun's rays, rapidly destroys guttapercha, rendering it brittle, friable, and resinous, and whatever retards or prevents this change consequently prevents the decay of the guttapercha. From a series of experiments undertaken in order to ascertain the cause of decay in guttapercha coating of telegraph wire, Dr. Miller showed that, where such wires were protected from the light, and in the case of cables kept completely and continuously submerged, he did not find any sensible deterioration of the guttapercha, and that those submerged in either fresh or salt water only increased slightly in weight from absorption of water, their tenacity and structure having undergone no change. Thus it is proved that, with certain precautions, this metamorphism into resin by absorption of oxygen can be prevented or arrested.

Guttapercha is insoluble in water, alcohol, dilute acids, and alkalies, and is soluble in warm oil of turpentine, bisulphide of carbon, coal-tar oil, caoutchine or oil of caoutchouc, and that of its own oil, for it yields by destructive distillation an oil similar to that yielded by caoutchouc under the same treatment. Ether and some of the essential oils render it pasty, and hot water, as is well known, softens it, absorbing a small quantity of the water, which is slowly parted with on cooling.

I now pass to a consideration of its industrial applications.

In the autumn of 1844 Dr. Montgomerie whilst in England delivered a lecture at the Society of Arts on guttapercha, and several persons obtained specimens to experiment upon. Foremost amongst these were Mr. Whishaw, who made and exhibited a tube and lathe band made of it; Mr. Hancock, so well known in connection with caoutchouc; and also Messrs. Keene and Nickels, who made arrangements with Messrs. Wilkinson and Jewesbury to import the article for them from Singapore. The first importation by this firm (now Messrs. J. W. Jewesbury and Co.) was in 1845. A copy of the original account sales of this, the *first* importation, I believe, into England, now lies before me, and is for "58 bags of gum gutta *ex* 'Queen' @ Singapore," and weighing 42 cwt. 1 qr. 3 lb. The patents for processes in working guttapercha, taken out by Messrs. Keene and Nickels, were sold to the "Guttapercha Company" in the City Road, a firm amongst the first in the field, which has sustained its position ever since.

In 1844, Mr. C. Hancock took out a patent for "certain improvements in corks and other stoppers, and a new composition or substance which may be used for, as a substitute or in preference to, cork," this new substance being guttapercha. This alone, or in combination with caoutchouc and mixed with ground corks or wood sawdust, was the material of which the corks were to be made. The guttapercha alone, or combined *with caoutchouc*, was to be dissolved or masticated by

processes similar to those used in the manufacture of caoutchouc and applied to similar useful purposes. The utility of this combination of guttapercha with caoutchouc was early acknowledged, for a mixture of one part of guttapercha to two of caoutchouc combines the properties of both, and can be vulcanized together equally as well as if separate. Mr. Brooman, in 1845, proposed to use it as an artificial fuel, either alone or mixed with small coal or coal dust, pitch, sawdust, or tar, the resulting soot to be utilized as a pigment for printers' ink. He purified his guttapercha for the purpose of making varnishes, by passing it several times through a cleansing machine connected with a tank of water, and using steam and rollers. After cleansing, the guttapercha was to be kneaded like caoutchouc, mixing with it colouring matters, sulphur, caoutchouc, &c., with the addition of French chalk to improve its smoothness and emery to roughen it. Thus prepared, it was moulded, stamped, embossed, or cast, and in its plastic or solid form applied to the same purposes as was caoutchouc, and by means of the same machinery. He also formed threads of guttapercha, by placing a roll of it in a cylinder and forcing it through a dye of the required size by means of a piston, cooling the thread as it issued forth with cold water. Such thread, either alone or covered with flax or silk, he plaited into hats, caps, bags, whips, bridles, cordage, &c.

Mr. Nickels also introduced guttapercha sheeting as a substitute for vellum, leather, and paper, in binding and covering books.

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Mr. Keene, in 1845, introduced improvements in the manufacture of boots, &c., by coating or covering them with guttapercha, using guttapercha as soles, by uniting the different parts with guttapercha cement; also in making boots entirely of guttapercha compounds, and sulphurizing such boots if required. Mr. Bewley patented the manufacture of piping for syringes, tubes, hose, &c., by forcing guttapercha in a state of plasticity or solution in a cylinder, through a hot disk with holes, into a cup, from whence it passed round a core and descended in the desired tubular form into a receiver of cold water.

In 1846, Mr. Hancock introduced several improvements in the manufacture of guttapercha and its application, alone or combined, with other substances. He first cleansed it by Mr. Brooman's patent, and then, whilst still in a plastic state, further purified it by forcing it by means of screw power through numerous holes in the bottom of a cylinder and through strainers, or he prepared the guttapercha in a state of solution and filtered it through flannel, wire gauze, or felt, and then evaporated the solvent. Guttapercha so treated he combined with caoutchouc, orpiment, or some other sulphuret or sulphur itself, and applied heat in order to impart to it new characteristics. He converted it into a cellular or spongy mass, by incorporating with it alum, carbonate of ammonia, or other volatile substances, and placing it in heated moulds, till the expansion due to the volatilization of the substances so incorporated should force the guttapercha into the form of a sponge. Also for *rendering* guttapercha and its compounds more soft

and pliable, he subjected it to the action of a sulphur compound, either in the form of sulphurous acid gas, or a solution of sulphurous acid; or covered it with a paste composed of sulphuric acid and charcoal, and then applied heat. The addition of wax or tallow rendered it more soft and pliable. He also steeped the guttapercha in an alkaline solution of soda or potash to diminish or remove its acid smell, and in the case of cast or moulded articles, he brushed over bronze powder to give a metallic surface. In order to prevent stretching of the straps or bands, used in driving machinery, &c., Mr. Wharton introduced metal wires into such straps.

In 1847, Mr. Hancock introduced further improvements. In order to cleanse the guttapercha, he first sliced it by a machine with three radial knives. The guttapercha so cut was then passed through various rollers, a "mincing" machine, consisting of parallel blades working with a scissors-like action, and lastly through pressing rollers, being carried from and to the various machines by means of endless bands. To sulphurize or metallo-thionize the guttapercha, he added 6 parts of sulphuret of antimony or hydrosulphuret of lime and 1 part of sulphur to 48 of guttapercha, and then boiled the compound under pressure.

In 1848 Messrs. Barlow and Forster obtained a patent for covering telegraph wires with a mixture of guttapercha and gum kowrie, or with guttapercha alone, the wire being placed between two heated fillets of the substance and made to adhere by passing between two rollers. In the same year Mr. Ricardo patented a machine with a

pair of grooved rollers, through which the wires passed, placed parallel between the fillets, the action of the rollers being to bite nearly through the guttapercha, and allow of the several wires so covered to be easily separated. Mr. Truman, in the same year, also introduced guttapercha as a moulding for the mouth instead of metal, in which to fasten artificial teeth. In 1850 Mr. E. W. Siemens invented improved machinery for coating telegraphic wires with guttapercha, consisting of a cylinder or cylinders in which the guttapercha is placed, and by the pressure of a piston forced through a die, through the centre of which the copper wire passes and thus becomes surrounded. It was also about the same time applied to printing calicoes, &c., by having a pattern impressed on it, its flexibility allowing of its being easily fixed round a cylinder. Mr. Bessemer in 1851 also used it to give an ornamental surface to leather or woollen fabrics for bookbinding, &c., by covering the substance with a thin film or coating of guttapercha, and, whilst the film is still hot, rubbing over its surface a piece of cotton wool charged with bronze or other metallic powder. Mr. Westley Richards also patented, in 1852, a combination of cork and guttapercha for gun wads, and guttapercha in the form of cores for hollow conical projectiles; guttapercha was also used in the production of artificial flies for fishing, and dumb jockeys. Mr. Perkins, in 1854, patented it for taking castings by making a mould of the desired pattern with plastic guttapercha, rubbing over with plumbago, electroplating it, running soft metal over the electroplated surface so as to

give a substantial back, and then removing the gutta-percha. Numerous patents were from time to time taken out in which guttapercha was the base, such as mixing it with ground cocoanut shells, asphalte, pitch, sawdust, &c., for purposes of economy and as a ready means of holding such substances together. In 1856, Mr. Rider patented improvements, which consisted in adding 1 part of sulphur to 66 of gutta-percha, exposing the compound so formed to a heat of 235° to 245° Fahr. to expel any volatile ingre-dients, and then vulcanizing it, using for the purpose a heat of 255° to 265° Fahr. Mr. John Macintosh's telegraphic cables, patented in 1857, were made by coating the wire with guttapercha alone or mixed with caoutchouc; round this a bat or fleece of fibres was folded and pressed into the guttapercha, and over this another coating of guttapercha mixed with a quantity of iron filings. These are but a few of the many patented improvements, and will serve at least to show what great activity, industry, and ingenuity have been brought to bear on this one substance, in order to bring out and utilize to the full its varied and useful properties.

I now turn to a short detailed consideration of the manner in which it is manufactured, though the perusal of the various improvements to which I have directed attention, will have already given some idea of how it is carried out.

Guttapercha as received by manufacturers is very impure, from the presence of bark, sand, clay, and wood, and often stones, which have been inserted in

the centre of a block in order to increase its weight. It is generally in the form of irregular oval lumps or oblong blocks, though a great deal was sent over in grotesque shapes by the natives, who fashioned the guttapercha whilst plastic into monstrous heads, animals, birds, lizards, serpents, crocodiles, &c.

The first operation is therefore to purify the guttapercha, and to effect this it is first subjected to the action of a slicing machine. This consists of a powerful circular wheel of cast iron, with a thick rim in order to impart to it the momentum of a fly-wheel, driven by a band from the main shafting. In this wheel are two or three slots, in which knives resembling broad chisels are set. Motion being communicated to the wheel, a block of guttapercha is placed on a shelf fixed at the side of the wheel and inclining to it, so that the knives as they are brought round descend on the block and cut slices off. The knives can be easily removed and sharpened, and this becomes the more necessary from the frequent presence of stones, which often fly out and strike the operator. These slices have next to be softened, by placing them in wooden chests filled with water and heated by steam. They are then taken out in baskets and placed in a "devilling" machine, placed over and at one end of a trough of warm water, and consisting of toothed-iron cylinders driven by machinery. The guttapercha, as it is caught between these cylinders, is torn by their action into shreds and falls into the water below, advantage being thus taken of its lightness as it floats on the top of the water, the impurities

falling to the bottom. This spongy mass is removed with perforated or sieve shovels, thoroughly washed in cold water, and placed again in baskets to be dried. It is then packed in jacketed iron chests, heated by steam, till it becomes a soft but incoherent mass, and whilst in this state is thoroughly kneaded or masticated. These masticators, similar to those used in the manufacture of caoutchouc, consist of a cast-iron cylinder, with a movable lid and a central masticator in the form of a solid toothed axis of iron, which revolves. This process is kept up for some time, and has the effect of thoroughly incorporating the gutta-percha and rendering it consistent in quality throughout the mass, which becomes of a brownish-red colour. Various substances are added, either to increase its density or hardness, or simply colour it, such as orange lead, red lead, orange chrome, rose pink, vermilion, yellow ochre, sulphur, caoutchouc, gypsum, resin, &c., great care being taken to select such substances as are not injured by the application of the heat employed in their incorporation. When the action of the masticator has been continued long enough, the bolt of the door is removed, and the gutta-percha turns out of the cylinder and is caught by two men. The addition of other substances is made with great nicety, as by this means a product can be obtained either soft and elastic, or hard and rigid like bone or horn. The mass whilst still hot is taken to the rolling machine (two steel cylinders), and as the gutta-percha passes through it, is received on an endless band of felt, which brings it back again to the rollers,

a fan blowing on it to cool it as it passes along. It is re-rolled till it becomes compressed and the air driven out, the distance between the rollers being lessened before each succeeding rolling. These sheets, if required to be cut narrower, for driving bands for instance, are rolled on two drums, between which is placed a metal frame with slits, in which knives are fixed at distances according to the width of the required bands, and as the sheets pass over the knives and are thus divided, they are wound on the second drum. The bands are then passed through a simple machine, where they are made of a uniform width by means of rollers, and have their edges rounded. To make string, a sheet is pressed between rollers with parallel knife edges, which indent the guttapercha sufficiently to allow of the strings being separated by hand. These strings are placed in a trough of warm water, and the operator, standing between two such troughs, takes the strings in his hand, stretches and rounds them, and passes them over his shoulder into the second trough, and this is repeated till they are brought to the substance and finish required. Guttapercha string is used for many purposes, as it is easily joined, although it is not so strong as an equal thickness of hempen string. To make soles for boots, the sheet guttapercha is cut into strips and lengths by a machine with a series of knives, and these are cut to the proper shape by a hollow die. Tube making is another important branch of manufacture. The piping or tube machine, something like those used to make macaroni, consists of a cylinder to hold the plastic

guttapercha, and a piston to force it through a moulding or die piece which governs the size of the pipe. Running through the centre of the moulding piece is a core of metal of the size of the internal diameter of the pipe; and when the power of the piston is applied, the guttapercha is forced around this core and against the moulding piece. Its internal and external diameter being thus governed, the tube is forced out of the cylinder and is received in a trough of cold water, which hardens it, the water that enters the tube preventing its collapse. To its power of resistance for piping I have already alluded, and this renders it very valuable for liquids, as it can be steeped in water, salt or fresh, buried in damp or marshy ground, withstand friction, and the attacks of marine insects. The pressure which it readily bears is more than sufficient to disrupt a leathern pipe and send it flying in pieces. For conveying water it has great superiority over lead, as it does not contaminate it. The facility with which it can be shortened, lengths added on, or a defective piece cut out with a knife and a perfect joint made either with itself or in connection with metal with the application of heat, renders it extremely valuable. Its acoustic properties are well known. The essential points required in any acoustic instrument is, that it should hold a large amount of sound in a small space, and yet not stifle the sound vibrations.

These qualities guttapercha tubing possesses in a high degree, and this has led to its employment as ear trumpets, stethoscopes, and other surgical apparatus, and domestic telegraphs or speaking tubes. Telekere-

phonas, as Mr. Whishaw first termed them, are now to be seen in almost every office and warehouse, as they afford an easy means of communication between different departments, and are valued as "muscle and time savers." In churches and other public buildings there are frequently pews or seats which have pipes communicating for a distance underground with the pulpit or platform, and thus enable deaf people to hear, the trumpet end being stamped or cast in the form of a carving or moulding, so as not to be easily distinguished from the surrounding ornamentation. The comportment of guttapercha with acids and alkalies renders it of great value in the laboratory and the manufactory. It yields certainly to strong nitric or sulphuric acids, but is unaffected by them if dilute, as also by concentrated hydrochloric, hydrofluoric, or acetic acid, or by chlorine or cold fixed oils. This leads to its employment for siphons, flasks, funnels, pipes, bowls, ladles, measures, and carboys, to a large extent, instead of lead or glass. In vitriol works it is found that, whereas buckets made of the best leather have to be renewed twice a week, those made of guttapercha last three months. It is also extensively used for driving belts, as its non-injury by grease, oils, water, acids, alkalies, and chemicals generally, and its facility for being joined render it highly valuable. It is also employed largely for lining cisterns.

But the greatest use to which guttapercha has been put is that of covering telegraph wires, and it may be safely affirmed that to guttapercha we owe the present dimensions of our system of telegraphy. Electricians

had in their hands the power, by means of a wire, of holding converse with the globe, and transmitting their thoughts or records of their actions as quickly as they could utter them; but the wondrous messenger required to be curbed in with a strong hand, or else it wandered anywhere but in the desired direction, any attraction causing it to fly off at a tangent. In other words, what was wanted was some substance, cheap, lasting, and easily applied, which by covering over the wire should thoroughly insulate it, so that the current of electricity may not be broken or diverted; and at this critical period guttapercha was brought to notice, and soon proved itself to be better adapted to the purpose than any other material. In the notice of patents, I have alluded to the manner in which telegraph wires are coated. The first method was by laying the wires parallel on a strip of hot guttapercha, and then placing a second slip over them, causing adhesion and division of the individual covered wires by means of rollers. The second method, now generally adopted, is by charging cylinders with plastic guttapercha, and then by means of a piston forcing it through a "moulding piece," through the centre of which the wire is gradually drawn and gets completely coated to the thickness allowed. The wire as made is passed through cold water and coiled on drums. For submarine cables, coatings of tarred rope and galvanized iron wires are wound to give additional strength and security. Telegraph wires are also of great use in exploding mines, blasting rocks, and subaqueous explosions from a distance.

One of the earliest applications, namely, to boat-making, is now historically connected with Arctic exploration. Captain Forsyth, who had command of an expedition sent out by Lady Franklin in search of her husband, took out a guttapercha boat with him, and he states that "whilst the other boats constructed of wood suffered much by the cutting of the young ice, the guttapercha boat was not in the least damaged, and returned to England in almost as good condition as when she left, although she underwent all the rough work of the voyage." Its weight was only 18 lb. Mr. Snow, who was in the Albert expedition, gives even stronger evidence in its favour. The boat attached to this expedition had a skeleton of wood, and the guttapercha sides had a covering of caoutchouc on the outside. Mr. Snow says, "Having in almost every instance had charge of the guttapercha boat, . . . I had good and ample opportunity of giving her a fair trial, . . . and at last I preferred her to any other; . . . and the old whalers 'considered her far superior for such service to the ordinary boats generally used.' One of the severest tests was in searching for a Danish settlement, when the boat had run through a stream of ice and resisted the different attacks it received; and as a memorial of our visit and the value we attached to the article of which our boat was made, the inlet we were then making our way through was called 'Guttapercha Inlet,' a name it will no doubt always retain and be remembered by among whalers." The severest trials which it endured, however, was about Whaler Point, where loose masses of ice at times lifted it completely

out of the water or threw it sideways on some craggy piece, but these difficulties were surmounted bravely. Any other kind of boat Mr. Snow considered would have been "crushed or stove on the instant."

As a decorative and fine-art material, guttapercha is largely used, in the shape of inkstands, pen-trays, baskets, watchstands, vases, and many other familiar articles.

This part of the manufacture gives employment to many clever modellers and stampers. A design being selected, a model is prepared and electrotyped, and a cast is taken for a mould, the mould being filled up with lead at the back in order to bear the necessary pressure. The guttapercha being carefully placed between the mould, is then subjected to pressure, and when cold is taken out and trimmed. Some of these casts are very beautiful, as the guttapercha will reproduce the finest lines. "Marbling" guttapercha is effected by mixing up together guttapercha of different colours, and this is done so skilfully that old oak and other woods and also marbles are beautifully imitated. Each operator has a slab heated by steam and a hot-water bath to carry on his operations. These various articles are varnished with a solution of guttapercha, and thus acquire a glass-like brilliancy and surface. Solutions of guttapercha in coal naphtha or other solvents are effected in large vertical cylinders, fitted with a stirring apparatus, and this solution is largely used as a cement for waterproofing and as a varnish. The applications of guttapercha are legion, for it is used as a substitute for leather, papier-mâché, cardboard,

wood, millboard, paper, metal, &c., in which a substance, which will withstand rough usage and the action of water, alcohol, dilute acids, and alkalies, is necessary or desirable.

There have been from time to time many substances recommended as substitutes for it, and some of them have been tried, such as the Cattimandoo and other Euphorbia inspissated juices. Pauchontee, the juice of *Bassia eliptica* of Dalziel, and the Mudar, the juice of *Calatropis gigantea*, have attracted much attention, but have never been introduced into commerce. The "Balata" gum of British Guiana, a product of *Sapota Mulleri*, is a valuable substance, and met with a ready sale, but none has been imported for a considerable time. It was sent over in a state of great purity, and in its qualities it stands about intermediate between caoutchouc and guttapercha.

INDIARUBBER OR CAOUTCHOUC.

By James Collins, F.B.S. Edinburgh, &c.

This very interesting substance is known in this country under the names of India or Indian Rubber, Rubber, Caoutchouc, or Gum Elastic. Of these names I prefer that of Caoutchouc (pronounced Kowk-chook), though in the following account it will be found that the words are used indifferently. Caoutchouc is the inspissated milk or juice obtained from various shrubs and trees, natives both of the old and new world. This milk is found in certain branched or anastomosing tubes termed *Cinenchyma* (so called from the movements of the fluid in them), or lactiferous (milk-bearing) vessels. The tissue is most abundant in the middle layer of the bark; this latter, as is well known, consisting of three layers, the first or outermost being generally of a more or less corky nature, and largely developed in the cork-oak; the second and usually thin layer, as seen best in milky-juiced trees; and the third, or that next to the wood, called the liber, most largely developed in fibrous plants. Many plants, even the dandelion, contain caoutchouc, but the trees and shrubs furnishing it in sufficient quantities for commercial purposes are found only within certain limits of heat and moisture, &c. Thus all the commercial indiarubber is obtained from trees in districts within

the isotherms, or having an equal heat of 70° Fahr. with a mean annual temperature of 76°, not falling lower than 61°, and an annual rainfall of about 90 inches, great moisture being one of the chief characteristics of the districts where such plants grow best. I shall now give an account of the different varieties of caoutchouc known in commerce, together with some information respecting the plants yielding them.

The different kinds of caoutchouc known to commerce may be thus classified:

American.—Pará, Ceará, Pernambuco and Maranham, Carthagena, Guayaquil, Nicaragua, "West India," Honduras, and Guatemala.

Asiatic.—"Singapore," Java, Penang, Siam, Assam, Borneo.

African.—Madagascar and "West Coast."

To a description of these I shall chiefly confine my attention.

I. American.

Of the early history of American caoutchouc we have very interesting accounts. Herrera, in his description of Columbus' second voyage, says, "They," the natives of Hayti, "had other amusements, such as the game of ball, for which they had a house set apart, and they played it, so many on each side, without sticks or bats, for they struck the balls with any part of their bodies, and with great dexterity and nimbleness. And the balls were of the *gum of a tree*, and, although large, were lighter and bounced better than the wind balls of Castile." Juan de Torquemada, in his 'De la

Monarquia Indiana' (Madrid 1615), gives more explicit information. He says, "There is a tree which the natives call Ulequahuitl" [i. e. *Castilloa elastica*]; "it is held in great estimation and grows in the hot country. It is not a very high tree; the leaves are round and of an ashy colour. This tree yields a white milky substance, thick and gummy, and in great abundance. To obtain it, the tree is wounded with an axe or cutlass, and from these wounds the liquid drops. The natives collect it in round vessels of different sizes, called in their language, 'xicalli,' but by us calabashes. In these they allow it to settle in round balls, of the size most convenient for the purposes to which they are about to apply them. When quite set they boil them in water, in which state the gum is called 'ulli.' The Indians who have got no calabashes smear their bodies over with it, for nature is never without a resource, and when it becomes dry they remove the whole incrustation, which comes off in a very smooth membrane, its thickness depending on the will of the party collecting. They then make it into balls and boil them as before. Anciently, they used to play with these balls, striking them against the ground, and making them to rise to a great height. But in the game of pelota it was not struck against the ground, but caught upon the hip or shoulder.

"From the ulli an oil is extracted of great value in various applications. It was formerly much used by the natives, nor have they forgotten its properties now, for it is soft and lubricous, and of especial effect in removing any tightness of the chest. The oil is ex-

tracted from the ulli by heat; it starts out in a manner to excite admiration, leaving nothing to compare to it. The oil is drunk mixed with cocoa, and, indeed, it softens any other medicine, however hard its quality. It is also found of great advantage in stopping hæmorrhage, for which it is taken internally. The coagulated ulli is so strong in itself, that a breastplate made of it no arrow will pass through; for, being of a nature leathery and membranous, it ejects the point. The kings and nobles were accustomed to make shoes of the ulli, and to order the fools and jesters, the humpbacked and dwarfs of the palace, to be shod therewith, in order to make them sport, for the wearers could not step without falling, which, with their awkward actions, gave rise to much jesting and merriment. Our people, i. e. the Spaniards, used it in waxing their cloaks, which were made of coarse canvas, so as to make them resist water, and, in truth, it is of great effect in resisting water, but not so the sun, for the rays thereof melt it."

The first accurate information about the species *Siphonia* or *Hevea*, which yields Pará caoutchouc, is that given by M. Charles Marie de la Condamine, who together with three fellow-members of the French Academy started in 1735 for South America on an Astronomical Mission. He found these siphonias or seringas in great abundance. Writing of them he says: "The rosin named cahout-chou in these countries of Quito adjacent to the sea, is very common on the banks of the Maranon (or Amazon), and serves for the same uses. When it is fresh they work it with

moulds into what shape they please, and it is impenetrable by the rain; but what renders it most remarkable is its great elasticity. They make bottles thereof which it is not easy to break; boots and hollow bowls, which may be squeezed flat, and when no longer under restraint resume their first form. The Portuguese of Pará have learnt of the Omaquas to make squirts or syringes thereof, which have no need of piston or sucker; they are made hollow, in the form of a pear, when scooped, having a little hole at the small end, to which a pipe of the same size is fitted; they are then filled with water, and by squeezing them they have the same effect as a common squirt! This machine is mightily in vogue among the Omaquas; when they meet together by themselves for any merry-making, the master of the house never fails to present one to each of his guests; and the use of the squirt is always the prelude to their most solemn feasts." This use of the milk led to the Portuguese name, "Pao di Xirringa," i. e. the "Syringe Tree."

Pará Caoutchouc.—Of all the various kinds of caoutchouc found in commerce, this is the most valuable, and consequently obtains the highest price. Pará caoutchouc is furnished by the following trees: *Hevea Guayanensis* of Aublet (known also by Persoon's name of *Siphonia elastica*, and Willdenow's of *Siphonia cahuchu*), a tree 50 to 60 feet high, with a trunk 2 feet to 2 feet 6 inches in diameter, greyish and thin, and white light wood; and by *H. Braziliensis*, a lofty, handsome tree, branching from the base, and yielding the caoutchouc, which is most abundantly exported;

H. spruceana, a smaller tree than the last; *H. paucifolia*, a large tree, 40 to 50 feet high; *H. rigidifolia*, a tree 30 feet high; *H. discolor*, a tree 25 feet high, which is sparing in its milk; and others.

These trees are known by various vernacular names, such as Caoutchouc, Caú-cho, Seringa, Xeringue, Borracha, Hevé, &c., the collectors of the caoutchouc being called in Brazil "Seringueiros."

The Seringa trees are large, the trunks yielding a very pure and good caoutchouc, and growing abundantly in the humid forests of tropical America, especially along the Amazon and its tributaries. The seeds are employed for baiting fish, and also yield by expression an oil of a clear violet colour, used in the preparation of varnishes, &c. The trees abound on the low islands in mid-river and along the banks of the river Amazon from the Island of Marajó at its mouth, to its source. The chief Pará district is between the Tocantius and the Zingu, and along and between the Tapajoz and Madeira, on the Rio Negro, Casiquaiari and Uaupés, tributaries of the Amazon. It occurs also on the plains of the Orinoco, in French Guiana, &c. For nearly all our definite information relative to these trees we are indebted to the researches of Dr. Spruce, an intrepid botanical traveller, to whom I have been personally indebted for valuable manuscript notes on the subject. The climate of the Amazon valley, where these trees best grow, has been so well and graphically described by Spruce, Wallace, Bates, and others, that I need only observe that it is remarkable for uniformity of temperature and for regular

supply of moisture. From June to December is the dry season, and from January to May the wet. The heat is generally not above 87° in the afternoon, or below 74° at night, the mean for the year being about 81° Fahr. It is in these dense moist forests that caoutchouc trees luxuriate. The collection of the Pará caoutchouc commences as soon as the waters of the river Amazon have subsided, viz. in August, and continues till January or February, the trees literally standing in water during the wet season; during the whole time the milk being much too aqueous to be of use. The milk is at first of the consistence and colour of cream, but on exposure the particles of caoutchouc coalesce, leaving behind a whey-like liquid. Each morning the collectors visit the trees that have been incised the preceding evening, and take away the milk which has run from the cuts. These have been made with a knife or machete, from the trunk to the roots, while on either side oblique cuts at short distances meet the central line or cut, forming channels down which the milk runs to the receptacles at the base of the trees. Sometimes a greater quantity is obtained by binding the trees with cords or bands formed of the stems of climbing plants, called lianas or sipós, but this generally results in the death of the tree so treated. At other times a quantity of bark is stripped off, or the tree is even cut down. The milk is then poured over clay or wooden moulds, and the coating dried by means of a gentle heat. Nuts of certain palms are put into a pan, or a pot with a narrow neck, those of the Urucuri (*Attalea excelsa*) being most gene-

rally used. These nuts are then "toasted" over a fire, and give off a thick white smoke, in which the caoutchouc is held, until a sufficient coating is obtained, when it is taken off the mould. Caoutchouc so prepared, when cut, presents a beautiful laminated appearance. Smoke does not blacken the caoutchouc, as generally stated, or even colour it in the least, the brown appearance of Pará caoutchouc being due to the absorption of oxygen from the air, as anyone may prove by cutting a thick piece through and noticing how soon the white centre becomes darkened by exposure.

Another and more modern method is adopted to prepare caoutchouc in Brazil, which consists in treating the milk with an aqueous solution of alum, and then subjecting the caoutchouc to pressure to get rid of the moisture. This is generally done at the collectors' homes, and is the more popular, as it does not necessitate a lengthened stay in the unhealthy vicinity of the trees. Sulphur too is also used in the preparation of Pará caoutchouc.

Caoutchouc appears in commerce in several forms: 1st, flat pouches or "biscuits," a very fine, carefully prepared caoutchouc made by successive dippings and "smoked," and with one side cut open, for the purpose of withdrawing the mould; 2nd, "bottles," made in the same manner; 3rd, "Negro-head," or "surnamby," consisting of the scraps of rubber left after the preparation of the finer descriptions, rolled into large balls or blocks, sometimes 12 inches in diameter, and often very much adulterated; 4th, loose "scrap."

The export from Pará in 1869 is as follows:

			Tons.	cwt.	qrs.	lb.
To London and Liverpool	161,987 arrobas.*					
To European continent	20,514	„				
To New York	182,843	„				
Total	365,344	„	= 4558	2	2	22

Maranham caoutchouc appears occasionally in commerce, and has the general character of that of Pará.

Ceará.—This caoutchouc, which resembles Pará, consists of reddish-brown pieces rolled up into balls or blocks, and known commercially as Ceará, "scrap." The trees are incised at the beginning of the dry season, and the caoutchouc picked at the end. It is good, but barky.

The caoutchouc obtained from these districts is the produce of a species of *Hevea*, and is also found in French Guiana, Venezuela, and Peru.

Pernambuco.—Caoutchouc is obtained from *Hancornia speciosa* (Gomez), known by the native names of Mangaiba or Mangabiba. The fruit is highly esteemed, and is of a yellow colour, a little streaked with red on one side, and about the size of an Orleans plum. The tree, of which there are three or four varieties, is about as big as an apple-tree, with small leaves and drooping branches, giving it the appearance of a weeping birch. It yields good caoutchouc, but is more valued for its fruit, which is sold in the markets of Rio Janeiro. It is found in the provinces of Rio Janeiro, Bahia, Pernambuco, Goyaz, Saint Paul, Sergipe, Ulinas Geraes,

* An arroba = 25½ lb.

Rayal, &c. Its caoutchouc is somewhat like that of Pará, but is seldom exported.

I next come to the consideration of the Ulé group of caoutchoucs, known in the English market as Carthagena, Guayaquil, Nicaragua, "West India," Honduras, and Guatemala caoutchoucs. These are all obtained from a species of *Castilloa*, of which two species are described.

1. *Castilloa elastica*, Cervantes.—This tree, mentioned by Don Vincente de Cervantes in an inaugural lecture on botany, published at Mexico in 1794, is one of the loftiest and most luxuriant trees of the forests which adorn the hot north-east coast of Mexico, with a stem three to four yards in circumference, and very straight, and the bark smooth, soft, and thin. The branches are alternate, horizontal, and hairy at the upper end, and the leaves alternate, a foot and a half long and seven inches broad, and covered with stiff hairs. The tree is called Ulé by the natives.

2. *Castilloa Markhamiana*, Collins.—This new species, published in my official Report, is named in honour of Mr. Clements R. Markham, C.B., of the India Office. This tree is smaller than the last, and its caoutchouc is said not to be so good. The margins of its leaves are serrated, and of a different form to those of *C. elastica*. It is called Ulé-Ulé by the natives, and is found chiefly on the Isthmus of Panama.

The climate where these trees flourish is warm and humid, the rain falling in Nicaragua for eight or nine months in the year. The juice is most advantageously collected in the dry season, the difference being about

50 per cent. more than in the wet season. A tree 18 inches in diameter will give 20 gallons of milk under the most favourable circumstances, each gallon yielding 2 lb. of good dried caoutchouc. The following description of the method of collection in Nicaragua will answer for all.

NICARAGUA CAOUTCHOUC.—The Hulero, as the collector of caoutchouc is called, makes a ladder of climbing plants, if unprovided with *guachos* or hooks, and fastens it to the tree as high as possible. He incises the tree with an axe by one of two ways. One is by making a long vertical cut with diagonal cuts running into it, as in Brazil; and the second, encircling the tree with one spiral cut from top to bottom, though in large trees two such cuts are made, the second being in the opposite direction to the first. At the bottom, an iron spout is driven which conducts the flowing milk into pails. In the evening it is passed through a sieve to free it from bark, &c., and then run into barrels.

To bring about coalescence of the caoutchouc, the juice of certain plants is added, such as the *Ipomœa bona-nox*, a convolvulaceous plant. This juice causes the caoutchouc to separate into a soft mass, smelling like fresh cheese, floating in a brown fluid. It is subjected to pressure by a plank or iron roller, and dried. When these planks are not obtainable, the addition of water brings about the desired effect, but takes a longer time.

NEW GRENADA.—The caoutchouc produced here is known in commerce as "Carthagena," and is imported in the form of sheets of $\frac{3}{4}$ inch thickness. It has

a somewhat "chewed" appearance, resulting from pressure. In colour it is black, of good quality, though at times "tarry," probably from the admixture of a "trunk resin" with the milk, through too deep an incision.

ECUADOR, or "Guayaquil" caoutchouc, is so called from its port of shipment, and is sent away in large plates or lumps, of a whitish colour in the best kinds, the lowest quality being somewhat porous, and containing a disagreeable black staining liquid.

PANAMA caoutchouc obtained from these two plants is largely prepared, and chiefly exported to New York.

WEST INDIES.—Under the name of "West India," the best description of Central American caoutchouc is known. In none of the West India Islands, as far as I have been able to ascertain, is caoutchouc collected; though possibly Yucatan, Belize, or some or all of the Central Republics may contribute. This variety consists of numerous plates pressed together in blocks, and called "sheet," and is of great purity; and also a second kind, called "scrap," which is good, but barky.

GUATEMALA caoutchouc is the lowest American variety. It consists of sheets pressed together, with a large quantity of "tarry" matter mixed with it. This, I am told, has led some firms in Hanover to refuse to use it, as this "tarry" matter is said to disagree with the workmen.

MEXICO.—Here the *Castilloa elastica* has long been known, and its caoutchouc used by the Mexicans in *medicine, for* surgical instruments, and waterproof

garments. It has the same general characteristics as the rest of the Ulé group of caoutchoucs, and recently parcels of it have been sold in London.

II. Asiatic Kinds of Caoutchouc.

The credit of first bringing to the notice of Europeans the existence of caoutchouc in the East seems to belong to Mr. James Howison, a surgeon in Prince of Wales Island. In his paper on "The Elastic Gum Vine" of that island, published in the 'Asiatic Researches,' 1798, he says that the general way of obtaining the gum, was by cutting the plant into lengths of about two feet. By means of wax moulds he made himself gloves, boots, waterproof garments, and other articles. This plant was named by Dr. Roxburgh, *Urceola elastica*. The next discovery was in 1810, by Dr. Roxburgh himself, who receiving from Silheb a turong or basket filled with honey, as a present, found that the lining of the turong possessed greater interest to him than the honey, being of caoutchouc. He named the tree producing it *Ficus elastica*, familiar to us as a window and greenhouse ornament in this country.

I shall first speak of the caoutchouc produced in India and from the Malayan Archipelago from a species of *Ficus*.

Assam or Silheb caoutchouc, as it is sometimes termed, is the only kind obtained from India, and is the produce of the *Ficus elastica* of Roxburgh, known in Bengal as "Kusnir" or "Kasmeer." This tree is found along the foot and in the low tropical valleys of the *Himalayas* from the Mechi river on the Nepaul

boundary, at 88° E. long., to the extreme boundary of Assam, 79° E. long.; as well as in the low valleys of the southern mountains of the Brahmapootra valley. It is, however, only found abundantly in parts of these districts, where characterized by hot steamy valleys, with a heat of about 98° Fahr. The trees are cut with a knife, and the milk is received in holes prepared in the ground, or leaves folded up in a funnel shape. About 50 ounces of milk is the average yield of a tree, giving about 15 ounces of dry caoutchouc. To prepare the "loaf" kind, the milk is poured into boiling water, and stirred till it acquires some degree of firmness, and then dried. The small "ball" kind consists of strings of caoutchouc which has been allowed to dry on the tree. Assam caoutchouc, either in the form of large blocks or separate balls, is shipped from Calcutta in baskets made of split rattans, and generally covered with a "gunny" bag, such baskets weighing about 3 cwt. each. This caoutchouc, and indeed all caoutchouc prepared from a species of *Ficus*, has a peculiar mottled appearance; in this variety the colour of the various agglutinated juices ranges from cream or flesh to that of a pink colour, verging into red, and with a glossy surface. Its good qualities, however, are much injured by gross adulteration with sand and other impurities. In the Malayan Archipelago large quantities of caoutchouc are produced and exported to this country.

SINGAPORE caoutchouc is the produce of a species of *Ficus*, most probably of *Ficus elastica*. This caoutchouc is not the produce of the island itself, but is imported from Java, China, Manilla, Malay Peninsula, Penang, *and Malacca*.

The following Table by Mr. Hancock gives the imports at Singapore of caoutchouc for the years 1849–50 to 1854–5:

	lb.
From Java	358,736
„ Sumatra	763,280
„ China	1,680
„ Manilla	14,896
„ Borneo	3,024
„ Malay Peninsula	448
„ Penang and Malacca	253,568
„ Elsewhere	130,256

In 1849–55 only 723,968 lb. were produced in Singapore, and since this date it has been stated that none is now collected. "Singapore" caoutchouc has a bright red colour and mottled appearance, and is very hard in texture. It is shipped in similar packages to that of Assam.

JAVA caoutchouc is the produce of *Ficus elastica*, and the tree is there called "Pohon Kareb" or "Kohlelet." The natives incise the tree and allow the caoutchouc to dry on the tree, using the strings so obtained as torches, with which they search for edible birds'-nests. This caoutchouc has a mottled appearance, the colour being darker than that of Assam.

PENANG and SIAM produce caoutchouc of good quality, having the mottled and glossy appearance common to those produced by species of *Ficus*. CHINA, too, contains caoutchouc trees, and the *Ficus elastica* has been recorded as a cultivated plant in Hongkong, but there are no direct shipments; if we receive it, it is *viâ* Singapore.

Borneo caoutchouc is received in this country either from Sarawak, or *viâ* Singapore, and is obtained from *Urceola elastica*, and made its first appearance in English commerce in 1864 under the name of "gutta susu," the Malayalim for milk-gum. This plant is a climber, attaining at times the thickness of a man's body, with a soft and thick bark, and a fruit of a fine apricot colour, and containing ten to twelve seeds of delicious flavour enveloped in a pulp. There are three varieties recognized by the natives, viz. a, *serapit*, the most common; b, *petabo*, the best variety; and c, *menungan*, a variety yielding the greatest quantity. To obtain the caoutchouc, the plant is cut into lengths of from a few inches to 2 or 3 feet, and the milk allowed to flow into buckets, the operation being quickened at times by applying fire at one end of these billets. To coagulate it, salt water is added to the juice, through which means water becomes enclosed in little pockets by the coagulation, which commences on the outside of a film, and thus prevents the escape of the water. Borneo caoutchouc is white, soft, porous, or spongy, generally wet from the mode of preparation, and when old changes to a dull pink or red, and is often covered with a saline incrustation on the inside. It is of a good quality. There are in the same districts two or three other trees said to yield caoutchouc, but they do not appear to be utilized.

III. African Kinds of Caoutchouc.

Madagascar, termed also "Mauritius" caoutchouc, though not known so long in England as in France,

has quickly risen into favour. It is the produce of two or three species of *Vahea*, found also in the Comoro Islands, viz. *V. Gummifera*, Lamarck (called Vauqhina by the natives), *V. Madagascariensis*, Bojer, called Voua, and *V. Comoriensis*, Bojer, a beautiful climbing shrub, 10 feet high, with white, sweet-scented flowers, and fruit of the shape and colour of an orange. In Madagascar the natives prepare the caoutchouc by means of salt water or artificial heat. It is rather more pinky in colour, but otherwise much resembles that of Borneo.

West Coast.—One of the principal plants producing this caoutchouc has been identified by Dr. Welwitsch, the Portuguese botanical explorer, as the *Landolphia owariensis* of Palisot de Beauvais. It is known to the natives as "Licongue" or "Licomgue," and is described by him as a large climbing plant, 4 to 6 inches in diameter at a height of 2 or 3 feet from the ground. From this point it divides into several long thin branches, which are subdivided, climbing along the stems and larger branches of neighbouring trees, to which they fix themselves very tenaciously by spiral tendrils formed out of the indurated flower-stalks after the ripe fruit has fallen off. The fruit is like an orange, with a hard, reddish-brown shell, containing a sweetish acidulous pulp eaten by the natives. Other species of the same genus yield caoutchouc, and are distributed between 10° N.E. and 10° S.E.; and also on the east coast at the mouth of the Zambesi. It is collected in a very slovenly manner. Sometimes vessels are used to receive the milk, but more often

the natives allow it to run down their arms; and when a sufficient quantity has collected thus, they work it down, removing it in the form of a ring.

The chief districts of export are the Gaboon, Congo, Angola, Benguela, and Zambesi.

African caoutchouc is received in this country in the forms of "flake," round "ball," and "tongue," has a most disagreeable odour, is viscous, and is generally the least elastic of all the varieties.

There are three natural orders of these plants, thus:

Euphorbiaceæ: *Hevea* species.
Artocarpaceæ: *Castilloa* species, *Ficus elastica*.
Apocynaceæ: *Hancornia speciosa*, *Urceola elastica*, *Vahea* species, *Landolphia* species.

I have now mentioned the various varieties of caoutchouc known to commerce, and the following Tables give the prices, together with the imports or actual sales of the same, in London and Liverpool, during the period from June 1871, to June 1872. The prices quoted are those actually paid for the *best* descriptions of each variety unless otherwise stated. The *average* price is taken from the total of the various prices paid during the twelve months, and not from the highest or lowest prices alone.

TABLE I.—IMPORTS and PRICES of CAOUTCHOUC in London from June 1871 to June 1872 (based on the Monthly Reports of Messrs. Jackson and Till, Colonial Brokers, Mincing Lane, London):

Description.	Imports for 22 Months, ending June 1872.
East Indian	1347 tons.
Pará and West Indian	721 „

Prices paid, at per lb. during the same period, for the *best parcels only*:

Description.	Average Price for the year.
	s. *d.*
Pará	2 10
Singapore	2 0
Penang	1 9½*
Borneo	1 9
Assam	1 8†
West India	2 0
Guatemala	1 7
Guayaquil (pressed)	2 0¾
Carthagena	2 1
African	1 5
Madagascar	2 3

* Few parcels.
† The highest price paid was for a parcel of *great* purity.

TABLE II.—SALES and PRICES of CAOUTCHOUC in Liverpool from June 1871 to June 1872 (based on the Monthly Reports of Messrs. J. H. Rayner and Co., Colonial Brokers, Liverpool):

Description.	Sales.
Pará	3610 tons (imported during the year).
Carthagena*	1770 bales sold „ „
Ceará* ..	3320 „ „ „
Guayaquil*	480 tons „ „ „
African* ..	905 „ „ „ „
Honduras	A few bales.
Mexican ..	„

* The actual imports may be *slightly* lower, as at times a parcel may be re-sold for speculation purposes.

Prices paid at per lb. for best descriptions only, during the same period:

Description.	Average Price.
	s. *d.*
Pará	2 11
Ceará	2 0
Carthagena	2 1

Description.	Average Price. s. d.
Guayaquil (pressed)	2 1
African*	1 11
Honduras	1 11½
Mexican	1 10½

* This is for the best kind, which is new to commerce. It is the same description as the other kinds of African, but better prepared. The prices for African caoutchouc for June 1872 are: tongues, 1*s.* 8½*d.*; balls, 1*s.* 11½*d.*; niggers, 2*s.* 2*d.*; knuckles, 1*s.* 8½*d.*; and flake, 1*s.* 9½*d.*

Allowing all the varieties to be *equally pure*, their relative value may be taken in the following order:

Pará, Madagascar, Carthagena, Ceará, West India (sheet), Guayaquil (pressed), Singapore, Assam, Penang, Guayaquil (common), African, Borneo, and Guatemala.

In the case of such a very useful and highly necessary article as caoutchouc, the question naturally arises, how can we secure lasting supplies at a sufficiently cheap price, as it is a well-established axiom that we cannot long depend on the spontaneous products of the forests, or rely on the caprices of native collectors, and that recourse must be had sooner or later to cultivation. I have strongly urged this necessity, and will mention some of my reasons for so doing, as stated in my Report to Her Majesty's Secretary of State for India. I first showed the desirability of cultivating the *Ficus elastica* in India on as large a scale as possible, and also how the caoutchouc should be collected and prepared. The mode of tapping as generally practised is exceedingly hurtful to the trees, and I have recommended the use of a kind of "tapping" knife which should only cut through the bark and save the

wood from injury. Trees so tapped or bled should be allowed a period of rest of from two to three years. Proper metallic vessels should be provided to collect the milk, so as to prevent contamination with clay, &c.

As to the preparation of the caoutchouc, several methods are resorted to, which may be thus classified:

Group I. — Coalescence brought about by heat. Examples:

1.	Artificial heat (dry)	Pará, Madagascar.
2.	„ (hot water)	Assam.
3.	Natural heat	Assam, Ceará.

Group II.—Coalescence brought about by the addition of various substances:

4.	Alum	Pará.
5.	Liq. ammoniæ fort.	Pará, African (best kinds).
6.	An acid? (acetic acid?) ..	Pará.
7.	Certain plants	Nicaragua.
8.	Fresh water	Nicaragua.
9.	Salt water	Borneo, Madagascar.
10.	Sulphur	Pará.

Of these various methods that of dry artificial heat seems to be much the best, though aqueous preparation is also good, if means be taken to dry the caoutchouc by adequate pressure. The milk should be strained with a sieve before submitted to coagulation, to free it from accidental admixture of bark, &c. It should also be prepared in the form of thin cakes, to reduce the possibility of adulteration to a minimum. Thus two of the chief desiderata, *purity* and *dryness*, would be

secured. I have endeavoured to show the great desirability of the acclimatisation and cultivation of the Heveas yielding respectively Pará, Central American, Madagascar, African, and Borneo caoutchoucs, Castilloas, the Vaheas and Landolphias, and the Urceola.

The Pará caoutchouc is undoubtedly the finest known, and where the question of price does not interfere, is used for the most valuable articles. Madagascar caoutchouc comes next to that of Pará, and I mentioned that all of these trees would be improved by careful cultivation, and that the caoutchouc from them would be held in high estimation. Larger quantities of good caoutchouc at a cheaper rate is much wanted, and, if supplied, would lead to corresponding increase of activity in its industrial applications, which, with its properties, I shall now consider.

Crude indiarubber juice, when first obtained from the tree, has the appearance of a creamy substance, like cow's milk, and has a smell of cheese or putrescent milk. This juice consists essentially of a watery fluid, containing small globules of caoutchouc, not dissolved, but suspended or diffused in it. These particles are very small, of a spherical form, and, according to the measurements of Adriani, from $\frac{1}{204000}$ to $\frac{1}{50000}$ of an inch in diameter, the average diameter being $\frac{1}{122500}$ of an inch. The specific gravity of the juice varies much, according to the season, &c. If left to itself, it will gradually undergo a change by the caoutchouc coalescing and swimming at the top of the liquid in which it is

suspended. The percentage of caoutchouc in the juice is from 10 to 30, but it varies according to the season, and also the part of the tree from which it is obtained. In the wet season the milk is much more aqueous than in the dry, and the milk of branches less than that of the trunk, and this again less than the roots. Pure caoutchouc has a specific gravity of from 0·92 to 0·96, and is a form of hydrocarbon, that is, a body having only the elementary bodies of hydrogen and carbon as its constituents. Commercial caoutchouc, however, contains albumen, and this is said to be the cause of the coagulation taking place when the juice is boiled. This coalescence is brought about by exposure to the air, agitation, addition of water, &c., but when once effected, no means are known of rediffusing it again in its medium. A specimen of juice* examined by the late Professor Faraday gave: caoutchouc, 31·70; albumen, 1·90; a bitter nitrogenous substance soluble in water and alcohol, 7·13; a substance soluble in water and insoluble in alcohol, 2·70; wax a trace, and water containing a little acid, 56·37. Adriani examined the juice of *Ficus elastica* and found of water, 82·30; caoutchouc, 9·57; resin, soluble in alcohol but not in ether, 1·58; magnesia, combined with a peculiar organic acid, 4·49; a substance, soluble in water and

* The specimen examined by Professor Faraday, and given him by Mr. T. Hancock, is quoted in many standard works as obtained from *Siphonia cahuchu*. This could not be the case, as the specimen was obtained from the southern part of Mexico, where the *Castilloa elastica* grows, and not the *Siphonia*.

alcohol, but not in ether (sugar ?), 0·36; and an organic substance (dextrine), &c., 2·18.

Caoutchouc has not the formation of a texture, but is like a clear, strong jelly, and when pure is transparent, colourless, and elastic, and with a pearly lustre when in tension. When exposed to the air for a few months to diffused daylight, it gradually absorbs oxygen, and is converted into a viscid mass, and not at all elastic. This should be borne in mind, as I have known cases in which specimens placed in museums have speedily lost all their characteristics through the action of light. The fresh-cut edges of caoutchouc which has not been vulcanized can be joined together again, and be as perfect as any other uncut portion. It also contains much latent heat, as may be proved by stretching repeatedly a small piece and placing it against the skin, when the temperature will be found to have risen considerably, sufficient indeed, it has been found, to raise an ounce of water two degrees in fifteen minutes. The best-known solvents of this substance are rectified oil of turpentine, coal naphtha, bisulphide of carbon, washed ether, chloroform, and caoutchine. This last is obtained as a clear yellow liquid oil by dry distillation of caoutchouc, and is by some looked upon as the best solvent, and is very similar to oil of turpentine. The effect of solvents on caoutchouc is to first cause it to swell up and then form a ropy liquid, the caoutchouc returning to its original elastic condition on the evaporation of the solvent. It is also dissolved by fixed oils, and in such combinations is useful, though its elasticity is by this

means destroyed. It melts at 257° to 260° 6′ Fahr., but on cooling becomes a sticky mass, burns with a bright, luminous flame in the air, and, if distilled, yields other hydrocarbons besides the caoutchine or caoutchoucine already mentioned. Differences of temperature cause it to expand or contract slightly, and a few degrees below 32° Fahr. it becomes less supple, very slightly adhesive, and hardly extensible. Under pressure it condenses very slightly, a cube of $2\frac{1}{2}$ inches, under a pressure of 200 tons, condensing $\frac{1}{10}$ lb., and causing a fly wheel of 5 tons to start back with great violence.

The elasticity or stretching power is very great, and it can be temporarily deprived of this elasticity by forcibly stretching, and quickly cooling it, as also by plunging it in cold water and vibrating rapidly in the air. In this state it will remain if kept sufficiently cool, but when warmed it returns to its former dimensions. It is also one of the best non-conductors of electricity.

Long after these trees were known to scientific men, caoutchouc was only looked upon as a curiosity in this country. Dr. Priestley, in the preface to his book on 'Perspective' (1770), says: "Since this work was printed off, I have seen a substance excellently adapted to the purpose of wiping from paper the marks of black-lead pencil. It must therefore be of singular use to those who practise drawing. It is sold by Mr. Hairne, mathematical instrument maker, opposite the Royal Exchange. He sells a cubic piece of about half an inch for three shillings, and says it will last several years." Hence the name India Rubber.

The great need of some substance which would render garments waterproof was generally felt, and we find that as early as 1627 a patent was taken out by one John Jasper Wolfen "for the terme of fourneene yeres" "vse or ex̃cise, practize or putt in vse" "a newe invenc̃on for the making and p̃paring of c̃taine stuffe and skynns to hould out wett and rayne" . . . . Some of these early patents contain no specifications, but in others from six to fifteen different substances are mentioned. In 1791 the first patent was granted to Samuel Peal for the employment of indiarubber for waterproofing purposes. Gum, either prepared or in its native state, was to be spread over the article to be waterproofed with a brush, dried in a hot room or stove, and the application to be repeated till a sufficient coating had been given.

In 1813 a Mr. John Clark took out a patent for air-beds which were double cased, the inner one being inflated and rendered air proof by the application of a solution of caoutchouc in spirits of turpentine boiled in linseed oil.

In 1820, however, the first of a series of patents was taken out which marked what we may term the commencement of a commercial era in the history of this interesting substance. It was granted to Mr. Thomas Hancock, who has been styled by Mr. Robinson (who established the 'Mechanics' Magazine') the "father of this important and wonderfully increasing branch of the arts." This encomium was justly merited, as during the thirty-six years he was in the trade he introduced many improvements, not the least of which

was the writing * a history of the particular trade in which he was engaged. The patent was for the application of caoutchouc to the wrists of gloves, trousers' straps, braces, belts, stocking garters, laces for boots, &c. Difficulties, however, arose in the practical working of this in the mode of attachment, it being found that the straps split and broke away from the puncture of the needle; but Mr. Hancock surmounted this by making the ends thicker, and improved the manipulation by the use of wet cutting tools, hot water baths, &c. The rubber was cut off in rings from small thin bottles, the form in which they were imported, and the pieces covered with tape, leather, &c., the caoutchouc being stretched while the covering material was applied. The next difficulty was, what to do with the waste cuttings, digestion in a Papin's digester giving but a treacly mass of little use. Fresh edges of unmanufactured caoutchouc readily unite, though old do not; and Mr. Hancock took advantage of this by cutting out with a hollow punch pieces of an inch square and packing them in an accurate mould: and by submitting these to pressure, he obtained large blocks from which he could cut sheets with a knife kept constantly wet with water. This could only be done, however, with the thickest and best bottle rubber, and he conceived it to be necessary in some way to give to the rubber as many *new* surfaces as possible. Speaking

* 'Personal Narrative of the Origin and Progress of the Caoutchouc or Indiarubber Manufacture in England,' by Thomas Hancock, of the firm of Charles Macintosh and Co., London and Manchester. London, Longmans and Co., 1857.

of his difficulties at this time, he says: "These discouragements were for a time very vexatious, as my means were but slender. Although I was making way, I could perceive that unless some mode could be found to unite not only the waste cuttings, but also a large proportion of the material as imported (which was so uncouth in form, and irregular in surface and size, that it could at present be turned to no useful account), my object would not be attained. My mind being solely directed to this subject, I saw the prospect of new applications to an enormous extent of a substance, with the properties of which I was daily becoming more and more conversant. I did not give up the pursuit; the object I had in view seemed within my reach by what I had already done, but the object itself I could not yet grasp."

The result of his experiments was the construction of a machine to "tear" the rubber, and consisted of two pieces of wood bolted together, enclosing two others, the upper portions of which were grooved out in the form of a hollow cylinder. In the centre of this was a solid cylinder attached to a spindle, both studded with teeth, space being left between for a small charge of rubber to be operated upon. This machine he called at first a "pickle," but afterwards a "masticator," a name now very familiar to all. Till about 1832 the existence of this machine remained a secret. His experimental machine only took a charge of about 2 ounces, but larger ones were made and worked by horse or steam power. The rubber was put in at a small door at the top of the machine, the

door then securely closed, and the machine put in motion. When the operation had been continued long enough, it was found that the heat and motion to which the caoutchouc had been subjected had rendered it homogeneous, and that it turned out as a rough, corrugated, plastic ball, which could be easily pressed into blocks. It was also found that if the rubber was previously passed through rollers, it facilitated the operation. This preliminary operation is called "devilling" by some, a stream of water effectually washing out the sand, clay, and other impurities. "This discovery," remarks Mr. Hancock, "was unquestionably the origin and commencement of the indiarubber manufacture, properly so called." To heat the rubber before entering the masticator, it was at first placed in earthenware pans in an ordinary baker's oven, afterwards in metal vessels surrounded by high-pressure steam, the heat applied being about 300° Fahr. The rubber so treated was easily soluble in good oil of turpentine. A mixture of tar, pitch, or asphalte, with caoutchouc, was patented by Mr. Hancock in 1823, for use, instead of "tarred" felt, under the copper of ships.

In the same year (1823) Mr. Charles Macintosh, of Glasgow, obtained a patent for rendering two fabrics waterproof by uniting them with a solution of rubber, called "waterproof double textures." These fabrics are now universally known as "Macintoshes." The history of the circumstances which led to the invention of this celebrated article is thus given by his son, Mr. George Macintosh: "Upon the introduction of coal

gas into Britain for the purposes of lighting apartments and the streets of towns and cities, the manufacturers of the article found that the tar and other liquid products resulting from the process accumulated upon their hands, in the shape of a most disagreeable and inconvenient nuisance. Mr. Macintosh, chiefly with a view to the production of ammonia to be employed in the manufacture of Cudbear, entered, in 1819, into a contract with the proprietors of the Glasgow gasworks, to receive for a term of years the tar and ammoniacal water produced at their works. After the separation of the tar into pitch, to suit the purposes of consumers, the essential oil termed naphtha is produced; and the thought occurred to him of its being possible to render this also useful, from its powers as a solvent of caoutchouc, or indiarubber. By exposure to the action of the volatile oil termed naphtha, obtained from the coal tar, he converted this substance into a waterproof varnish, the thickness and consistency of which he could vary according to the quantity of naphtha which he employed in the process. Mr. Macintosh obtained a patent for this process in 1823, and established a manufactory of waterproof articles, which was in the first instance carried on in Glasgow; but eventually he formed a partnership with Messrs. Birley and other friends in Manchester, where operations on a very extensive scale were entered upon, and the business carried on under the firm of Charles Macintosh and Co." Mr. Hancock obtained a licence from Mr. Macintosh to use his patent (this was before they entered into partnership with each other), and found that by using

equal quantities of oil of turpentine and naphtha, the smell of the articles was mitigated and that his masticated rubber required less solvent to produce the effect of solution. Later on he manufactured Mr. Macintosh's goods for him.

The mode of manufacture was to make a solution of caoutchouc in naphtha, to spread the solution over each fabric separately, and when the surfaces became somewhat clammy from the volatilization of the solvent, to bring the two varnished surfaces face to face; perfect adhesion being effected by passing through rollers, and drying the fabric in a temperature of from 100° to 140° Fahr.

In 1824 Mr. William Philip Weise took out a patent to render cloth and other materials for wearing apparel waterproof by a composition of equal parts of caoutchouc, shellac, gum mastic, gum amine, and gum sandarac, dissolved in spirits of turpentine or other medium. In this the skeins intended for weaving were saturated, the material in its woven state having a hot iron passed over it or passed through hot rollers.

It had long been thought that if the milk of caoutchouc trees could be obtained uncoagulated, a perfect waterproofed article could be made.

This practice of coating articles with fresh juice had long been practised in Brazil by Indians, and, as has been seen, a patent had already been taken out in this country. Articles so prepared were without the disagreeable smell imparted by the solvents necessary to be employed where the coagulated rubber was used. Mr. Thomas Hancock accordingly took out a patent in

1824 to use the crude juice, but after great exertions it was found that supplies in sufficient quantities could not be obtained. However great the care of transport, very little was found in the casks in an uncoagulated state, and this, added to the cost of freight and other causes, soon led to the conclusion that the process possessed nothing to recommend it. About this time various applications were made by Mr. Berry's patent of caoutchouc in the production of stoppers for bottles, waterproof cordage, play-balls, substitutes for leather, tubing, hose pipes, straps, harness, &c. The artificial leather material was made by saturating felt, carded cotton, cotton, wool, and hair with caoutchouc, and by combining it with hemp, flax, and other fibrous materials. It was also applied to boots and shoes, air-beds, pillows, life preservers, to cushions for billiard tables, to the edges of wheels, rollers, &c.

The tubing was made of cut sheet rubber, and afterwards with alternate layers of cloth saturated with the solution. An improvement in the application of caoutchouc to gloves, surgical articles, &c., consisted in stretching the article on a frame, coating the part with solution, placing two or three hot stretched threads of rubber over it, covering it with leather or other material. On the article being removed from the frame, the resilient action of the caoutchouc contracted it, giving it a neat corrugated or "shirred" appearance. Patents were also taken out for bearings for carriages, gas-holders, beds, and teasles in yarn manufactures, guards or caps for the legs of horses, ropes, &c., in which caoutchouc was used.

In 1832 Mr. James Vincent Desgrand took out a patent for a "Method of weaving elastic fabrics." In this, cords or strings of caoutchouc were spun in a loom, as the warp or woof with silk or other fabrics, or as both: attrition being effected by using a hot iron or rollers to the fabric so produced.

The "waterproof double texture" was applied to the making of beds for invalids, but the first produced were remarkable for the facility with which people could roll off them instead of laying on them. This was obviated by making them in tubular or "reeded" compartments: an application extended also to the production of pillows for the head and neck, &c.

Great difficulties were encountered at first in manufacturing waterproof garments on Mr. Macintosh's plan, from the fact that tailors would persist in puncturing the garments with their needles and pins, and in making close instead of loose-fitting garments; the first fault, allowing rain to enter; and the second, arresting perspiration, and giving doctors grounds for condemning the use of such articles.

Various improvements were soon made out in the preparation, &c., of caoutchouc: one, by Mr. Christopher Nickels, for cutting threads of caoutchouc by revolving circular knives and discs, the caoutchouc being prepared by rolling and milling, and the threads so treated to be used for spinning.

The invention of the elastic web is ascribed to a German. To effect this, threads of caoutchouc were plunged in hot water, or wetted by the fingers, and stretched on frames or rollers. The amount of latent

heat eliminated by this operation was sufficient to scorch the fingers of an unpractised person. After remaining in this condition for a little time and kept cold, the caoutchouc becomes passive, or "set," all its elasticity being quiescent. In this condition it is woven in a braiding or other machine, and its resilience restored by passing a hot iron over it. Applications of the substance were also made to the backs of books instead of sewing; as a source of gas, though it was soon found to be too expensive; and as a timber preserver, as patented by Mr. Bethell. It was also mixed with stone and other materials for roads, and used as blankets for the bed in machines for printing on fabrics, &c., as well as for life preservers, diving dresses, air pipes, and pontoons. These pontoons made of strong canvas, coated with caoutchouc, have many advantages over those of other materials. They are very light, easily inflated, and when not in use can be carried on horseback, and thus treated as light baggage on a rapid march.

In 1843 Mr. Alexander Parkes patented "Improvements in preparing solutions of certain vegetable and animal matters," by the use of eupion and bisulphuret of carbon or other sulphuret of carbon. Eupion, which is the Greek for "good fat," is the most volatile portion of an oil obtained from the distillation of the tar of hard woods, and is a hydrocarbon which readily dissolves caoutchouc. Bisulphuret, or as it is now termed bisulphide or disulphide of carbon, is a highly inflammable volatile liquid, obtained by passing the vapour of sulphur over glowing coke or charcoal,

when union of the two elements takes place. Caoutchouc was one of the substances submitted to a mixture of these agents for obtaining a solution. Mr. Hancock improved still further upon it by the application of solvents in the state of vapour to rubber.

In the month of November of the same year, a patent was granted to Mr. Walter Hancock for the production of a caoutchouc of a changed character by the addition of sulphur under the influence of heat.

The history of the discovery of this process, called by Mr. Brockledon "vulcanizing," is highly interesting. In 1842 he showed Mr. Hancock pieces of rubber brought by a person from America, which were said not to stiffen by cold, nor to be much affected by solvents, heat, or oils. The smell of sulphur was perceivable in these samples. However, nothing seems to have come of it. Mr. Hancock was then engaged in an endeavour to divest caoutchouc of its adhesiveness, so as only to require a single texture in its application to waterproofing, fabrics, &c., and also to render it unaffected by cold. He succeeded in producing articles perfectly inadhesive, by the combination of caoutchouc with silicate of magnesia, and compounds of this silicate with fuller's earth, whiting, ochre, asphalte, &c. With the idea of rendering caoutchouc unaffected by cold, &c., he toiled away after business hours in his laboratory at Stoke Newington, lighting his own fires, for he never allowed anyone to enter his laboratory. Noticing a change of appearance for which he could not account in some experimental scraps of caoutchouc containing sulphur, he tried numerous experiments in this

direction, saving the most likely specimens, and testing by means of ice their behaviour under the influence of cold, as an indication of a change. Knowing that if rubber be submitted to the heat necessary to melt sulphur, viz. 240° Fahr., it would not be sufficiently high to injure it, he began by immersing slips in a sulphur bath, noticing the action from time to time, and at last obtained a specimen of a black colour and a hard and horny character. Here, then, was the key to his problem, and it only remained for him to so regulate the conditions to bring about the kind or variety of the change desirable. He also found that absorption of the sulphur by the caoutchouc took place at 240° Fahr., and that, by raising the heat to 270° or 280°, at the end of an hour complete vulcanization had taken place. He at once saw that by blending the sulphur with caoutchouc by means of rollers and masticators, the material could be dissolved and used for waterproofing, or moulded into any form to any degree, and capable of being wrought with tools. His patent was enrolled on the 21st of May, 1844, his experiments previously being repeated for him by Professor Graham and Mr. Arthur Aitkin. He soon found that he could expedite the production of vulcanized caoutchouc by blending the sulphur and rubber by heated rollers, and when in the form required, vulcanizing it by the application of steam heat, a process used up to the present time. To deprive the rubber so treated of any excess of sulphur, he submitted it to a strong solution of sulphate of soda or potash at a temperature of about 200° F. Not only were previous applications

found to be improved when made of vulcanized caoutchouc, but many new purposes were discovered for this to which the unvulcanizable article could not be applied. In fact, as is the case with all highly useful substances, would-be inventors did not know where to place bounds to its application. It was known that it would resist shot but not a bullet, the effect of the latter being to pass through, leaving but a crack and not a regular hole. One person offered to prove to the Duke of Cambridge its power of resisting shot by wearing a breastplate of it and being shot at, and accordingly applied to Mr. Hancock for the caoutchouc necessary, and it was only by that gentleman's proof by firing with a pistol at a board covered with caoutchouc, and showing the bullet hole in the board, that he desisted from carrying out his offer of being made a human target.

I will now briefly consider the importance of this invention. Many as were the applications of caoutchouc in its natural or unaltered forms, it seemed at one time as if it were likely to fall into disuse, or that its applications would have to be circumscribed from certain defects. Its manufacture had been carried on in two ways: first, by direct mechanical treatment of the gum after simple cleansing; secondly, by the action of some volatile solvent, and the application of the solution to some material, so that a film of caoutchouc was left on the surface. But it was found that such caoutchouc became rigid and inflexible under the influence of cold, while it softened and decomposed in the sun and hot weather, this defect alone rendering many

manufactured goods a total loss, and causing, it is said, the failure of several American firms. Contact with grease or any kind of fatty or essential oil quickly dissolved it, and perspiration had the same effect, though slower in its action. It was also very adhesive and sticky, so that any substance pressed against its surface was quickly joined and could not be separated. By continued use or tension it lost its elasticity, and, beside this, an unpleasant odour pervaded goods produced by its solution. But at the most critical time the method of vulcanization was discovered, which, while preserving and even heightening the properties for which it was valued, added to it stability and divested it of the defects which were so many barriers to its present success and future extensions. Caoutchouc so treated was found to have almost perfect elasticity at *all* temperatures below 239° Fahr., and not to become adhesive below a heat of 212° Fahr., while fresh cut edges did not unite as in the unchanged substance. Its resistance to solvents too was very marked, though not absolutely insoluble, and its capability of being inadhesive and unaltered by cold, heat, water, or solvents, opened at once a new field of industry.

In Germany the honour of discovering *vulcanization* is ascribed to Hindersdorf, of Berlin, and in America it is claimed for Nelson Goodyear, who seems to have occupied the same position in America as Messrs. Hancock and Macintosh did in England. The history of the discovery in America by Mr. Goodyear is thus given. In the summer of 1838 he became acquainted with a Mr. Nathaniel Hayward, who had been em-

ployed by the Eagle Company at Woburn, where he had been in the habit of using sulphur by impregnating the solvent with it. This was done to assist in the *drying* of the caoutchouc. Mr. Goodyear purchased this claim, and took out a patent for its use, but *not* for the purpose of *vulcanization*. The defects of goods thus manufactured rendered them a total loss, and the only way that he saw out of the difficulty was to use the caoutchouc milk as it came from the trees in an unaltered state. The hint was not lost on his Irish servant, who appeared next morning with his trousers coated with the milk. He sat down to his work, but through the heat of the stove and his body he speedily became glued to his seat, and the legs of his trousers entered into partnership, so that he had to be peeled before being released from his ludicrous position! This convinced Mr. Goodyear of the uselessness of his idea. Experimenting on the effect of heat on caoutchouc, one piece containing sulphur came accidentally in contact with the hot stove, and, becoming charred, gave him the idea that if he could stop this process at the right point, he should obtain the product which he desired. Rubber so changed he called "soft rubber," in contradistinction to "hard rubber," to be mentioned hereafter. Mr. Charles Goodyear's first patent for the vulcanization of caoutchouc was issued June 15, 1844, and in its reissue of December 25, 1849, he says that when caoutchouc was combined with sulphur by the application of a high degree of heat, he obtained good results, but still better by adding carbonate of lead in addition, in the

proportion of seven parts of the latter to twenty-five of rubber and five of sulphur, by weight, using a temperature of from 212° Fahr. to 350° Fahr., or thereabouts. His method was to dissolve the rubber in spirits of turpentine, or other essential oils, grinding the sulphur and white lead, like paint, and spreading the mixture evenly on a smooth surface or upon glazed cloth, from which it could easily be separated afterwards. The ingredients could also be incorporated by passing them through heated cylinders. The sulphur could either be incorporated in the solid form, spread on the surface, or combined in the gaseous state with the caoutchouc by means of heat. He states that the heat producing the best results is about 270°, and the rubber so treated must be gradually brought to this heat to prevent blistering.

On March 25, 1846, a most important patent was taken out in England, by Mr. Alexander Parkes, for vulcanizing caoutchouc by a cold process. His patent was for improvements in the preparation of certain vegetable substances, consisting in the mode of obtaining "the change" upon caoutchouc, &c., by the employment of a solution of chloride or hypochloride of sulphur in bisulphuret or sulphuret of carbon, coal naphtha, or turpentine, &c.; and on the immersion of the articles in this solution for a few minutes, the desired change is effected. Caoutchouc in the dry state, if kneaded with a certain amount of dry chloride of sulphur, slowly underwent the same change, and whilst hot could be pressed into any desired shape. Caoutchouc, previous to being submitted to the

"changing," could be combined with wool, flax, cotton, wood or cork dust, earths, oxides of metals, and with other gums. By this process, however, only thin sheets could be subjected to this method, as in the case of thick sheets, the action on the outside would have proceeded too far before it had penetrated to the centre. After the articles were taken out of this bath, they were placed in a hot chamber, and then washed in water or in a solution of caustic potash or soda. The proportions for the bath are given as forty parts of sulphide of carbon to one of chloride of sulphur.

Numerous applications were made for patents to use vulcanized caoutchouc in the production of various waterproof articles by the Parkes method. The rubber was moulded or engraved, and then submitted to the same process to harden and give permanence to the surface, or after being so changed by either of the processes, it was rendered horny, and capable of being wrought with tools. Buffers for railway carriages, packing for engine joints and valves, were also patented, as well as for telescope and such-like tubes, buttons, knife and razor handles, &c. Kamptulicon was made by spreading masticated caoutchouc, mixed with cork dust or other matters, on both sides of woven fabrics, wire gauze or perforated metals, and afterwards rolling, and printing or painting patterns on the surface. Mosaics of the same substances were produced by colouring with pigments and cutting in different forms, and fastening down the desired pattern with caoutchouc solution. Boots and shoes, wholly or in part, had long been made, but goloshes

turned out by the new process, that is by being vulcanized afterwards, were much superior. Combs, backs of brushes, &c., were soon made of it, as it was found applicable to all the purposes to which horn, whalebone, bone, tortoiseshell, ivory, &c., had been applied, and with this advantage, that it could be coloured, and also moulded or stamped into any form before being submitted to the vulcanizing or hardening process.

In 1851 Nelson Goodyear took out in America a patent for the manufacture of vulcanite, hard or inflexible rubber, or ebonite, as it is variously called. In it he says, that when only two substances are used, he takes half of caoutchouc to half of sulphur, which when subjected to heating, becomes by his process a hard, stiff substance. A still better result is gained by the introduction of magnesia, lime, or their carbonates or sulphates, the proportions of these differing, though not less than 4 ounces of sulphur to 1 lb. of caoutchouc must be used. Shellac is also advantageously employed in addition to these. The mixture so prepared is to be submitted for six to ten hours to a heat of between 250° to 300° Fahr. In this patent it will be seen that no mention is made of articles so manufactured having the "*spring-like property under flexure found in whalebone.*" This new property, however, was inserted in a patent reissued in 1858 to Mr. H. B. Goodyear, the administrator of Nelson Goodyear, and was opposed by a Mr. Austin G. Day, of Connecticut, the latter claiming flexible caoutchouc as his invention. It was denied, too, before the Patent Court, by Professor B. Silliman, that such a large

quantity of sulphur was necessary, or would produce the result ascribed by Goodyear, and considerable doubt has been thrown on this part of his patent. The use of rubber for dental purposes, and thus called dental vulcanite, is claimed by Charles Goodyear also. This substance consists of a mixture of caoutchouc, sulphur, and vermillion, the latter being added to give a flesh colour to the product. A mould of the gums is taken and the teeth fixed in, and then subjected to the hardening effects of vulcanization. The proportions given by Dr. Wildman are 12 parts of caoutchouc, 6 of sulphur, and 9 of vermillion; and after being moulded into the required form, it was submitted to a heat of 310° to 320° for 1¼ hour or thereabouts.

In 1867 and 1868 patents were taken out in America by Messrs. Newbrough and Fagan for hardening caoutchouc by the addition of iodine and bromine. Caoutchouc (or any other gum) is rolled or worked into sheets, and placed one above another with layers of powdered iodine between them, and the pack worked between heated rollers under pressure until the iodine is thoroughly incorporated. These are cut or moulded as required, and then baked for 30 minutes at a temperature (dry heat preferable) of 230° to 330° Fahr. The proportion of iodine is regulated as the caoutchouc is required to be inflexible or elastic, using for an elastic substance 2 ounces of iodine to 8 ounces of caoutchouc; and for a solid, nearly inelastic substance, 4 ounces of iodine to 8 of caoutchouc. The material can be coloured by the addition of pigments, and rendered inodorous by immersion in liquor ammonia.

Another of their patents is a combination of iodine and bromine with caoutchouc. This is done by adding to iodine half its weight of bromine, the difficulty of manipulation being obviated by adding to each before combustion oil of turpentine, with one-fourth of its weight of sulphuric acid, thus preventing the formation of an explosive compound. Caoutchouc so treated will harden, when submitted for about an hour to a heat of 250° Fahr. Three ounces of this paste of iodine and bromine is added to a pound of caoutchouc, a larger proportion of the latter being used if a more elastic substance is desired, with a heat from 200° to 320° Fahr., lasting ten minutes to one hour and a half. Colour can be imparted to it by the addition of pigments before subjection to the process.

A third patent is the combination of bromine. The caoutchouc is cut or moulded into the desired state, and then immersed in bromine for such a length of time, that when exposed to the air it will become hard. To prevent this taking place during immersion, one part of chloroform is added to nine parts of bromine, or a portion of caoutchouc is dissolved and coated over a mould and placed in the solution, the coats being repeated till a sufficient thickness is obtained.

The same firm patented the combination of iodine and sulphur with caoutchouc. Here the sulphur is first boiled in spirits of turpentine, and a solid matter settles at the bottom. This is taken out, washed with dilute sulphuric acid, and dried. The iodine is treated in the same way, sulphuric acid being added to the oil of turpentine to prevent explosion.

Equal portions of this prepared sulphur and iodine are melted together, and the composition on cooling is incorporated with the caoutchouc at the rate of 3 ounces to 1 lb. This is then moulded or formed into the desired shape and placed in an oven, the temperature during the first 15 minutes being raised for 5 minutes to 320° Fahr., and then quickly lowered for an hour to 250° Fahr. Colouring materials can be added before hardening, and the product so obtained is hard, tough, and durable.

The proprietors of the Nelson Goodyear patents also endeavoured to prove that their patents embraced these of Newbrough's, by stating that the hardening of the caoutchouc was due to the action of the sulphur alone, and that the effect of the iodine and bromine was only to carbonize and deteriorate the caoutchouc. But from the testimony of Professors Torrey, Silliman, and Chandler, and of Mr. Newbrough, it was shown that iodine did have the effect of hardening, and that the use of sulphur in the production of "Dental Hard Rubber" was to prevent the iodine acting on the vermillion or colouring agent and turning it yellow. Mr. Newbrough says that the proportions he uses is 1½ ounce of iodine, 1½ ounce of sulphur, and 7½ ounces of vermillion to 16 ounces of caoutchouc; and, moreover, that his rubber could be welded together. Thus it seems clearly to be shown, that the hard rubbers produced by Newbrough and Goodyear are distinct and different products. Numerous applications have been made of this substance, and patents taken out for the same; but I can only mention a few. The importance of providing trains with

cleansed from the clay, sand, &c., with which it is impregnated. This is effected by soaking it in a trough of hot water, which softens these foreign matters, and then passing it through deeply corrugated cast-steel rollers, which grind it with immense force, whilst a jet of water falls on it and washes out the foreign matters in a muddy stream. This is repeated till it is thoroughly cleansed, and comes out in the form of a band or sacking of a yellowish or brownish colour. It is next taken to the kneading or masticating machine, a massive hollow cylinder of cast iron, with a solid toothed cylinder revolving inside, the motion of which causes the disengagement of the latent heat of the caoutchouc, which emerges like so much dark-coloured dough. When several of these lumps are ready, they are pressed in a cast-iron mould by screw or hydraulic power. The caoutchouc is then cut into sheets, if required, being fixed in a mould on a movable table, and brought up against a razor-like knife, moving with immense rapidity and having a tiny jet of water playing on it. The sheets can be cut as thin as paper, and have a beautiful velvety and lined appearance. To cut *tape* for elastic goods, a "bottle," or round slab of caoutchouc, is taken and fixed to a circular shaft, where its circumference is exposed to the action of a knife revolving at the rate of 3000 times a minute, and kept constantly wet with water. Tapes are thus obtained of any length and thickness, and are cut into threads by being passed through guides over a revolving steel disc, a slot determining the width of the threads, which are so fine at times that 5000 yards of such thread weighs but a

pound. The ends are joined by cutting them obliquely and gently pressing, and they are then wound on reels by being passed through the wet fingers of boys to stretch and eliminate the latent heat. In this state it is kept for some days, by which time its elasticity has become passive. The threads so treated are taken to a braiding machine, and covered with silk or other material, and then woven into tissue at a ribbon loom, the elasticity being freed by warming it with a smoothing iron on a blanket, when it contracts to its proper proportions. For the production of waterproof materials, the rubber in a state of solution is strained and spread by machines evenly over the surface of cloth or other material, the cloth being drawn over a heated surface and dried. This waterproofing is applied from the coarsest sail-cloth to the most delicate linen and cotton cloths.

Vulcanizing is effected by the methods already noticed, either by immersing in a sulphur bath, by incorporating by rolling and subjecting to heat, or by Mr. Parkes' cold process, by which its plasticity enables it to be moulded into any form, even with greater facility than wax; or it is afterwards wrought with tools or turned in a lathe. The forms impressed on such articles are permanent, and, if subjected to pressure, they will regain their original form as soon as the disturbing force be removed. Vulcanite or ebonite differs only from ordinary vulcanized rubber, through the greater amount of heat to which it has been subjected rendering it hard, black, and horny. At a higher temperature than necessary to bring about this result, the rubber would become carbonized and decomposed.

FIBRES AND CORDAGE.

By P. L. Simmonds, F.R.C.I.

Cordage, the collective or general trade term for all kinds of cords, ropes, lines, ships' rigging, &c., is chiefly manufactured from hemp, at roperies in various parts of the kingdom, but especially near the great seaport towns of London, Liverpool, Greenock, Hull, Sunderland, Belfast, &c.

It is not only vegetable fibre that is, however, now utilized, for animal and mineral substances are employed to some considerable extent.

In 1852, Mr. Braithwaite Poole, in his 'Statistics of British Commerce,' estimated, from careful inquiries, which he had the opportunity of making amongst all the great railway companies, that there were carried over Great Britain annually the following quantities:

		Value.
	tons.	£
Cordage	50,000	2,000,000
Hemp	50,000	1,500,000
Bagging, &c.	10,600	320,000
Canvas	6,500	546,000
Coir	24,000	432,000

Now, if this approximate estimate was within the

mark at the period when it was made, the progress of commerce and manufactures will have largely increased many of these figures.

When it is borne in mind that there are registered as belonging to the United Kingdom and her possessions alone 37,000 vessels, making in all about 7,500,000 tons of shipping, the cordage necessary for rigging and working these becomes of importance, to say nothing of the various other uses for mines, landing and towing in canals, harbours, &c.

We imported in 1874, cordage, twine, and cable yarn to the value of 552,665*l.*, chiefly from Russia and the East (India and Ceylon), in about equal proportions; and we exported in the same year of the like material 128,722 cwt., valued at 361,282*l.*

There are in the United Kingdom 26 hemp factories, of which 19 are in England. These have 64 combing machines, 10,456 spinning spindles and 870 doubling spindles, 88 power looms, and 114 power-loom weavers. These factories employ 2234 hands, in about equal proportions of male and female.

The London Post Office Directory contains the names of 154 professed rope makers, besides eighteen others who manufacture wire rope; many of these, however, are mere retailers, while others are but the Metropolitan depôt or agency of provincial rope makers, such as Newall and Co., the Warrington Wire-Rope Works, Limited, the Edinburgh Rope Company, &c.

The cordage and twine exported from the United Kingdom annually, amount in quantity to an average of about 130,000 cwt., but in some years (as in

1863–4–5), the shipments have reached 165,000 cwt. The average annual value of the cordage and twine imported in the five years ending 1874 was about 500,000*l.*, and the value of that British made, exported, is from 360,000*l.* to 400,000*l.*

In all the large modern rope manufactories, machinery is employed which accomplishes the work more expeditiously and systematically than by hand. Machine spinning allows of the whole of the fibre being extended at full length and the strength of the material being obtained, whereas hand spinning does not admit of the like advantage in manufacturing.

In England, machinery for spinning threads from hemp is very generally employed at Newcastle, Hull, and other ports, and the ropes made by machinery are found to be 24 to 30 per cent. stronger than those spun by hand. Grease or tar is necessary in the manufacture of cables, to protect the threads from dampness. Fluid tar makes the material compact and binding. To obtain the best quality of rope, it is necessary to select threads of the same thickness, strength, expansion, and equal twist. Strands are composed of threads, and cables, of strands of three and four or more threads. There is a difference between strands of which cables are to be made and those intended for rigging or tackle, the latter being more twisted.

The fibres of hemp not averaging more than 3½ feet in length, they are necessarily overlapped among themselves and compressed together, so as not to be drawn apart. The required compression is best obtained by

twisting, the fibres being continuously drawn out together from a bundle, in the right quantity to produce the suitable size of yarn. The yarns are put together to make strands, and three or four of these twisted together make a rope, and three or four ropes a cable.

Ropes are designated as to size by their circumference, and as to length by fathoms. Their weight and strength vary with the quality of the hemp.

A rope cable is always composed of three strands, every strand of three ropes, and every rope of three twists; the twist is however made of more or less threads, according as the cable is to be thicker or thinner. A rope 2 inches in circumference and 120 fathoms long, is generally found to weigh nearly 1 cwt.

Hemp Manufacture and Cordage.—Hemp, now one of our principal fibres, has not been very long employed in Europe. In the time of Olivier de Serres, only a coarse fibre was obtained from it fit to make ropes and twine, and history cites as a curiosity two chemises made of hemp which belonged to Catherine de Medicis. All the linen employed up to the close of the fifteenth century was made of flax or cotton.

The imports of hemp into the United Kingdom, although not so great as those of flax, average over 1200 tons weekly. Hemp is imported in bales of from 2 to 4 cwt., and bundles of variable weight tied at one end. A bale of clean Russian hemp weighs 55 to 65 lb. (30 or 33 bales to the ton), of out-shot or

second quality 48 to 55 lb., and half clean 40 to 45 lb. Besides the fibre dressed and undressed in 1870, we imported 57,042 cwt. of tow and codilla of hemp, about 11,000,000 lb. of cable yarn of hemp, valued at 174,000*l.*, and 19,748 cwt. of cordage, &c., of hemp, of the value of 43,814*l.*

The tough, durable, and elastic fibres of hemp, are better suited for making cordage and canvas for shipping than any other substance yet known, and the quantity required to supply the navies and commercial marines of the world is immense. Hemp is not only employed for making cordage, common towelling, tarpaulins, &c., but canvas and sacking are largely made for home consumption and also for export, from hemp, tow, jute, and other fibres, chiefly for sacks for grain, flour, hops, coal, salt, &c., and for ships' sails.

Of sail-cloth and sails upwards of 4,700,000 yards are now exported annually, valued at 286,000*l.* Old canvas from the Royal Navy and mercantile marine meets with a steady sale for rope-making purposes. Bagging is largely made at Dundee and other places, of jute, old ropes, and other coarse stuffs, and sent to the United States for baling cotton, but this manufacture is now largely carried on by the Americans themselves, and a good deal of what is called "gunny bagging" is shipped direct from Calcutta to the United States.

The value of the bagging and sacks of British manufacture exported in 1874 was 1,750,000*l.*, and of sail-cloth and sails 286,339*l.*

The following figures will show the range of prices

per cwt. of undressed hemp, imported from various countries at the wholesale official valuation on entry:

	1855.			1860.			1870.			1875.		
	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*	£	*s.*	*d.*
Russia	2	3	0	1	10	0	1	12	10	1	15	4
Austria and Italy	2	3	0	1	16	10	2	0	9	1	17	9
Philippines	2	5	0	1	3	10	2	14	8	1	11	6
India	0	19	6	1	0	0	1	2	11	1	1	2

In order to show how great has hitherto been our dependence on Russia for this important fibre, I give the following table of the hemp imported from Russia during the present century in decennial periods.

	Total Import.	Annual Average.
	tons.	tons.
1801 to 1810	326,062	32,606
1811 „ 1820	266,186	26,619
1821 „ 1830	242,955	24,295
1831 „ 1840	288,657	28,866
1841 „ 1850	280,924	28,092
1851 „ 1860	261,990	26,200
1861 „ 1870	488,171	48,817
1871 „ 1875	95,458	19,091
Grand total and average for 75 years	2,250,403	30,005

The Russian war, the consequent scarcity and the great increase at the time in the price of Russian hemp, led our countrymen to direct their energies to the discovery of means which should make us independent in some degree of so indispensable an article for

and strands were also imported in 1870, valued at 455*l.*

Plantain Fibre.—Attention may be prominently directed to the varieties of the plantain and the agave or American aloe, because the fibre from these two plants are best known in the markets of Europe and America, and on account of the plants themselves being so widely disseminated through our colonial possessions. The younger stems of the plantain and the inner heart leaves of the agave furnish strong filaments of a silky character, which are naturally of a silvery whiteness, and which may be dyed of any colour, retaining their lustre and brilliancy. Deprived also of their gummy and resinous matter, and split or carded by the ordinary processes, they may be extensively adapted to many of the wants now supplied by flax and cotton. They are used at the present time for weaving into light fabrics, and also for damasks, the finer sort of furniture-hangings and upholstery, &c., generally.

One of the most promising materials for certain purposes is the fibre of the plantain, which has often engaged the attention of the tropical cultivator and merchant, though until of late years there was no great demand for new textile or cordage substances. The process of disengaging the fibre is so simple, compared with the elaborate processes attending the separation of hemp and flax; and the expense and labour so trifling, that it is surprising the raw material has not before this become an extensive article of commerce.

When we perceive how large the traffic in coir, the short prepared husky covering of the cocoanut, has

become, it is an earnest of encouragement for those who choose to embark in new undertakings for the supply of commercial fibres.

The magnificent herbaceous plantain forms a marked feature in the varied and profuse vegetation of tropical countries, and possesses a very widely extended range. The broad leaves gracefully overhang the succulent huge stem, which attains an elevation of from 8 to 15 feet, with a diameter of stalk from 1 foot to 2 feet. The stem is formed partly from the united petioles of the leaves; and they contain such a quantity of spiral vessels that they are capable of being pulled out by handfuls.

The *Musa textilis*, unlike the other two species of plantain, which can only be propagated by suckers, is easily raised from seed. The weight of a plantain stem will sometimes be 70 or 80 lb., of which 50 per cent. will be water. It is therefore too expensive to cart the stems to any considerable distance for preparation, and, in our colonies, machinery would require to be erected contiguous to the provision grounds, or "plantain walks," as they are termed. It is extremely desirable to know the quantity of fibre that can be obtained per acre, and the following calculations, which are the result of careful experiments, are worthy of record.

Cotton in America is an annual plant, subject to many deteriorating influences, particularly from frost or excessive rain, and a full average crop is considered to be one bale per acre, or about 4 cwt. Flax, also an annual, is regarded as a good crop at 6 cwt. per acre,

and hemp at 7 cwt. per acre. The plantain will yield of the best quality of fibre 48 cwt. per acre, besides the coarser qualities, consequently its produce will be as compared with that of cotton, twelvefold; of flax, eightfold; and of hemp, sevenfold. Moreover, the produce of the plantain from 500 acres would require to obtain the same quantity in cotton, 6000 acres; in flax, 4000 acres; and in hemp, 3500 acres. But flax and hemp, being exhausting crops, cannot be grown upon the same land oftener (at the utmost) than in a five year rotation. Therefore, to produce annually for seven years, 1200 tons of flax, would require the use of an estate of 20,000 acres, and for hemp, in the same way, 17,500 acres. But the plantain, not being an exhausting crop, would continue to produce its 1200 tons of fibre per annum without replanting for a term of twelve or fifteen years upon 500 acres. In New Zealand flax produces 1792 lb. per acre, the Moorva or Marool (*Sansiviera*) 1613 to 3226 lb. in two crops.

The manufacture of cloth and rope from the plantain is no new discovery, for the Indians and natives of South America have long been in the habit of using the fibre for these purposes.

The celebrated circumnavigator Dampier notices the process as carried on in the Indian Archipelago more than a century ago, as follows:

"They take the body of the tree, clean it of its outward bark and leaves, cut it into four quarters, which, put into the sun, the moisture exhales; they then take hold of the threads at the ends and draw them out; they are as big as brown thread; of this they make

cloth in Mindanao, called *sazgen*, which is stubborn when new, wears out soon, and when wet it is slimy."

Manila Hemp.—Manila rope is superior in strength to that made from Russian hemp. Hilly, wooded districts, and good soil are considered favourable for the cultivation of this plant; the best hemp coming from latitudes south of Manila, and from several islands as far as the 10th degree.

The mode of obtaining the fibre is very simple. The native strips the succulent stem that has been cut down of its outer covering or layer, which is cut into slips the whole length of the plant. Holding the slip with one hand, and pressing it firmly down on a piece of board by a strong broad-bladed knife (called a bolo), the operator scrapes off the pulpy parts, and leaves the fibre, which is the hemp. Machines have been introduced for this purpose, but do not find favour with the natives.

The wild plantain grows in vast abundance in some of the most northerly of the Spice Islands. In the island of Mindanao it fills great forests.

Another wild plantain, *Musa troglodytarum*, Linn., a native of the Moluccas, may yield some of the Manila hemp of commerce.

The plant is cultivated in many parts, but more especially in the provinces of Albany and Camarines in the south of Lugan. It is planted in the rainy season, and is propagated with ease in the same manner as the common plantains, 100 plants occupying about 1000 square yards of land.

The method of preparing the hemp is as follows: The tree, after having attained the age of between two and three years, is cut down and stripped of its folds; these are divided into pieces of 3 and 4 inches wide, and the pulpy or fleshy part separated by drawing them under a knife fixed for the purpose, so that the fibre is thus laid bare and is then placed in the sun to dry. If the plant be left on the ground for any length of time after it has been cut down, the hemp made from it assumes a reddish tinge unsuited to commerce. Fifty trees produce about 25 lb. of hemp. The production in the Philippines, in 1867, did not amount to much more than 400,000 piculs.

Like many of the misnomers of commerce, which are very difficult to correct, and which lead to sad confusion, the fibre of the wild plantain (*Musa textilis*) of the East is commonly termed Manila hemp (Abacá by the Spaniards), and I am obliged therefore to keep to the term here. This so-called hemp is the material so much used for making strong white rope for ships. The usual mode of preparation is as follows: When the stalk or stem has attained its full size, which is indicated by throwing out its fruit branches, it is cut close to the ground, and the stem, which will be 8 or 10 feet long below the leaves, again divided. The outer coating of the herbaceous stem is then stripped off until the fibres or cellular parts are seen, when it undergoes the process of rotting, and, after being well dried in houses and sheds, is prepared for market by assorting it, a task which is performed by women and children.

The chief supplies of this Manila hemp are derived from Leyte, Samar, Bohol, and the east coast of Negros (Dumaguete), in its more immediate vicinity; while from the great island of Mindanao it obtains a further supply, from the fine province of Misamis, and from the small island of Camiguin, which produces about 1000 tons of good hemp, nearly all of which goes to Zebu, and has of late years much improved in quality. The plantain tree, from which it is obtained, is propagated with great rapidity; and its quality, although frequently requiring selection from the cargoes of the coasting crafts, is generally good.

As it is mostly brought from the neighbouring islands to Iloilo as returns for paddy and native goods, it is only shipped to a small extent from that island in irregular quantities of from 100 to 250 tons per annum; but large quantities could be obtained from Leyte and Samar at considerably cheaper rates than those current at Manila. That which is intended for making cloth is soaked for an hour or two in weak lime water, again dried, and put up in bundles.

Some enterprizing American merchants have of late years almost monopolized the manufacture and trade of Manila rope, for which there is a large demand in the United States, for the use of their extensive mercantile marine. By the introduction of machinery the cordage has been greatly improved. The plan now adopted in manufacture may be thus described:

The first floor of the factory is occupied with the dressing machines, three of which are cylinders of wood covered with points of iron, 2 inches in length,

distant from each other about 1½ inch. These first open the fibre, which then passes to another machine, under a cylinder of much larger diameter, of which the points (cards) are smaller and placed together. By this the fibre is separated into a finer thread, and divested of the woody or refuse particles.

After this preparation the hemp passes between two iron cylinders, which compress it very strongly. From thence it is conducted to a smaller machine, which gives the first twist, and winds it on a bobbin of about 6 inches diameter. The dimensions of the cord are increased or diminished by means of an iron screw, which adjusts the diameter to the hole through which the fibres pass to the required size.

The demand for Manila ropes has been largely increasing, and as much as 30,500 tons per annum are often shipped from Manila to Europe and America.

The culture of this particular species of plantain has been largely extended of late years in the Philippines, and also in the northern part of Celebes. The cultivation is augmenting in the island of Leyti, and the quantity raised there in 1870 was estimated at nearly 160,000 cwt.

The decennial progress of our imports of Manila hemp direct from the Philippine Islands is shown by these figures:

	Cwt.
1831	2,262
1841	16,789
1851	22,835
1863	312,871
1871	206,902

And the following gives the yearly receipts and value in each year since 1863:

	Cwt.	£
1863	312,871 ..	421,004
1864	183,944 ..	309,253
1865	194,851 ..	309,520
1866	97,873 ..	222,384
1867	88,033 ..	222,328
1868	175,118 ..	415,116
1869	92,642 ..	245,348
1870	129,345 ..	354,498
1871	206,902 ..	454,509
1872	151,068 ..	344,639
1873	259,225 ..	547,298
1874	276,381 ..	512,431
1875	320,528 ..	505,140

The total quantity of this hemp exported from the Philippines in 1870 was upwards of 610,000 cwt., of which 164,000 cwt. were sent to Great Britain, and the bulk of the remainder to the United States.

AGAVE FIBRE.—Under the name of Mexican grass, we import into the United Kingdom about 19,000 cwt. of Agave fibre, cut short and cleanly prepared, which is used as a substitute for bristles in cheap nail and other brushes. It is locally called Itzle, and is very extensively produced in the Isthmus of Tehuantepec, and the higher lands of Mexico. One man can prepare about 4 or 5 lb. of fibre per day.

All the species of Agave, and particularly *A. vivipara*, familiarly termed silk grass, furnish a white but somewhat harsh or brittle fibre, possessing, however, useful properties. In the Canary Isles ropes are made of the agave fibre. The pita flax is in general use in Mexico

and Honduras. The manufacture of cordage from this plant employs large numbers of persons in the interior, and considerable quantities are consumed by the merchants in Peru in cording bales of merchandize, and for other such purposes.

Under the general names of pita, the *Brometia karatas* is extensively grown in Mexico. With proper care in cutting the leaves in due season, the fibre would be found not merely equal but much superior to hemp, while, from the natural whiteness of its colour, it would admit of being manufactured into the finest goods without undergoing the destructive process of bleaching. For maritime purposes, as for sails and cordage, it possesses many advantages over Russian hemp, which was fully established by a series of experiments made by Capt. M'Adam in the Royal Dockyard, Plymouth. It was found to contract much less than hemp from the action of heat.

The fibre of *Agave Americanus* is used for many purposes, and, as a proof of its great strength, Humboldt described a bridge where the distance of 838 feet was spanned by ropes made of the fibre of this plant, which actually formed the groundwork of the roadways. Some experiments made by Dr. Wight, with ropes of this fibre in India, showed that it broke with 362 lb., while rope made of sunn fibre broke at 404 lb.

Under the name of Sisal hemp, a large trade is now carried on from Yucatan to the United States in the prepared fibre of the leaf of *Agave sisilana*, which is used in rope making, and, when well made, it fetches nearly as high a price in the market as Manila hemp. Several thousands of tons are imported into the States

annually. An acre of plants will yield more than a ton of fibre at the end of four or five years. This plant has been introduced into Jamaica and propagated in the Botanic gardens there, and 8000 or 10,000 plants distributed over the island. The Americans are also growing it at Key West and the adjacent islands.

In Yucatan they get out this hemp by the simple and primitive manner of beating the leaf on a block with a club or mallet, and afterwards scraping it on a bench or a smooth log or pole, with one end on the ground and the other breast high. They employ a narrow piece of board with a triangular notch in the end, which is brought to an edge, and held nearly perpendicular when used. The leaf is laid on the pole, held with one hand, and scraped with the other. In order to get rid of the gum more readily, the beaten leaves are generally soaked either in water or in mud till they ferment; but from the nature of the gum, even a small amount of fermentation stains and weakens the fibres, although it materially facilitates the cleaning of them. Such is the difference in the value of these fibres got out by the two processes of fermenting the leaves before scraping, and that of beating and scraping the leaves at once, before fermentation takes place, that in the London market Sisal hemp is worth but 12*l.* per ton when the fibres have been soaked in water or mud; yet the same fibres are worth 50*l.* per ton when got out before fermenting by the aid of pure water alone. It would seem that this difference in the price of the fibre will warrant a good deal of labour and expensive machinery to get out the article in the better state.

When the fibres or filaments are obtained from the

exterior leaves of the plant, they are very strong and coarse, and are best adapted for cables, cordage, rope, canvas, sacking, the warps of carpets, and indeed for every description of this class of manufactures, where strength and durability are required. Ropes and cordage made of it are much stronger and more durable than those made from hemp; they are also lighter and more pliable, do not require tarring, by which hempen ropes lose much of their strength, and bear the alternations of dryness and moisture with little injury, while the difference in hygrometric action is considerable. Cables made from this material are acknowledged by the Admiralty Board to be much superior to those made from hemp.

The weight of pita or agave is one-sixth less than hemp; 30 feet of 1-inch rope, made of best hemp from the Royal Dockyard, weighing 12 ounces, and the same sized rope of pita, only 10 ounces.

In a vessel of 120 guns the weight of standing and running rigging, which in hemp is 54 tons 7 cwt. 3 qr., in pita would be only 45 tons 6 cwt. 19 lb., making a sensible reduction in top weight, and increasing thereby the stability of the hull, not to mention the saving in first cost.

In a five months' trial carried on many years ago in H.M.S. 'Portland,' the hygrometric action of the pita ceased after the third day, whilst in hemp it continued the whole time; a log line, 300 feet long, in pita, contracting only $19\frac{2}{16}$ feet, whilst a hempen one contracted $24\frac{6}{16}$ feet, being $5\frac{4}{16}$ feet in favour of pita.

It is highly advantageous, where lightness is a

desideratum, as for "Manby's apparatus," to have a line of the pita, weighing (according to Dr. Murray) 29 lb. dry, and on being wetted increasing in weight 4½ lb. only, with freedom from harshness or kink, coiling easier in consequence, and drying more quickly.

From comparative trials made at the French dock-yard, at Toulon, on ropes made from this fibre, and from hemp, the following results were obtained, both being immersed in the sea for six months, and exposed to the atmosphere for the same time.

Pita.	Weight supported.	Hemp.	Weight supported.	Difference in favour.
	lb.		lb.	lb.
Plunged in sea	3810	Plunged in sea	2538	1282
Exposed to air	3724	Exposed to air	3022	704
Plunged in sea	1935	Plunged in sea	617	1317
	9479		6167	3312

The superiority of the pita over hempen ropes is undoubted, and I annex an extract from a report by a Belgian engineer who has closely studied the question.

"Ropes made from the pita," says Mons. Chevremont, "possess a greater average strength by four times, than those made from hemp of the same diameter, and manufactured by the same process. By the operation of tarring, ropes of hemp lose nearly a quarter of their strength, while ropes made from the pita, from their nature, are exempt from this operation (their natural gum acting in lieu of tar), and their smooth

surface protects them from wear by friction; they are employed with the greatest success, to communicate rotative motion by means of pulleys, and last, for this purpose, ten times longer than hempen ropes of the same diameter. They have much less rigidity or stiffness, and it is well known that this stiffness, in ropes employed for machinery, offers a resistance which must be overcome, and therefore acts disadvantageously as a loss of power."

The specific gravity of ropes of pita, compared with ropes of hemp, is as 9 to 15. It is therefore clear that a rope of the vegetable silk weighs $\frac{6}{15}$ lighter than a rope of hemp, of the same diameter and length.

It will be readily understood how this relative lightness of ropes made from the pita is advantageous when employed for collieries and other mining purposes, both with reference to weight, and wear and tear of machinery.

Aloe Fibre.—In Russia aloe fibre fetches about 4*d.* or 5*d.* a pound. One manufacturer turns out about 20,000 lb. monthly, almost all of which is exported to France, where it is used for making hats, paper, cordage, stair coverings, matting, &c.

The process of fabrication is simple and inexpensive; the machinery consists of an engine of 4 horse-power, moving a pair of cylinders on a system of beaters or stampers. Close at hand are the reservoirs made of metal or masonry, which are used for washing or soaking. The leaf, cut green, is passed between the cylinders or under the stampers, by which means it is crushed without destroying the fibre; it is then left to

soak for six or eight hours, at the end of which time the separation of the various elements has taken place. Thirty leaves of aloe, two yards long each, yield on an average 2 lb. of fibre. It is packed at St. Denis in hanks and pressed in sacks, about 1209 lb. going to the ton measurement.

New Zealand Flax is from a plant of a very different nature from the common flax, the former being an endogen, the latter an exogen. The *Phormium tenax*, or New Zealand flax, is a liliaceous plant, of which there are several varieties, that have long been locally used for making rope and mats by the natives. It looks like the flag or sedge of our marshes, and is almost a weed in many parts of the colony. The difficulty of removing the resinous bark or coating has stood in the way of its extensive application, and rewards of 4000*l.* by the Colonial Government for a suitable cleaning machine have as yet failed to realize the object.

The *Phormium tenax* should take a high position among fibrous or filamentous substances. It is well known in the market here, and is daily assuming more importance.

This plant grows indigenous and abundantly throughout the whole of the New Zealand group and Norfolk Island, and has been introduced into various parts of the Australian Continent. It flourishes best in valleys and low marshy situations, although it also grows on high rocky soils, and thrives on the sea shore within the influence of the sea spray. It has been introduced with success in Ireland, the west coast of Scotland, and the Channel Islands; and there is little doubt,

that it might be advantageously cultivated in this country in suitable localities. Its introduction has also been recommended for the Mississippi Valley and other parts of North America.

A great deal of sacking for wool bales used to be made of it, and sent to Australia; and owing to the number of ropewalks in the colony, the import of cordage into New Zealand has now nearly ceased.

This fibre is looked upon by the colonists as the good angel of the country, which will yet shower wealth and abundance on the land. It is used by the settlers for anything, from a shoe-string to a saddle-girth. The rope made of it is a sufficient proof of its strength, and the native mats of its beauty, when manufactured.

What the flax has become to Australia, the *Phormium tenax* might be rendered to New Zealand.

The shoots should be tied and packed separately. Such as is of a bright silver colour is preferred, as it makes a substitute for Manila hemp. If it could be sent of a greenish tint, or indeed any colour but foxy, it would be liked for rope making. It has great similarity in appearance to jute, and might sometimes be mistaken for it; but jute on being bleached adheres strongly together, whereas the phormium forms more isolated groups.

Bombay jute is the fibre which New Zealand flax will most likely supplement in the sack manufacture. Jute is very much softer than any sample of New Zealand flax, though, of course, not so strong. The difference of fineness between New Zealand flax and jute will be understood from the fact, that enormous quantities of

jute are prepared in Glasgow to supply the London market with materials for false hair and chignons, a purpose for which flax is hardly delicate enough.

The census returns of New Zealand for the year 1870 show, that there were in the colony 161 mills working up the flax, which employed 342 machines, having in the aggregate 1450 horse-power. Of these about 90 or 100 were moved by steam power. There were 1706 males employed in these mills and 62 females. Every province of the colony devotes itself more or less to the prosecution of this industry. The quantity of flax manufactured in 1870 was 4458 tons, but it is only within the last three or four years, that any great quantity has been shipped. The quantity exported previous to 1864 scarcely amounted in value to 18,000*l.*, and from 1865 to 1868 only 4046 bales of the value of 13,464*l.* was shipped, but in 1869 the quantity exported from the colony was 12,162 bales, valued at 22*l.* 6*s.* per bale; and in 1870, 32,820 bales, valued at 24*l.* 2*s.* per bale.

Mr. John Pearce, of Christchurch, Canterbury, who has had nearly thirty years' experience as a manufacturer of different sorts of fibre into rope, gives the following scale of difference of weight of the same size of yarn (160 fathoms long), the first being Russian hemp, the second New Zealand flax.

	16	18	20	22	25
	lb. oz. dwt.	lb. oz. dwt.	lb. oz. dwt.	lb. oz. dwt.	lb. oz. dwt.
1.	4 0 0	3 8 14	3 3 3	2 14 9	2 8 15
2.	3 0 0	2 10 11	2 6 6	2 2 15	1 14 11

The above list is that of the most general size yarns used for the manufacture of cordage from Baltic hemp, and means that any one number of these yarns to a strand will make a three-strand shroud-laid rope, from which the number of yarns either for shroud or hawser-laid of any required size or number of strands are to be ascertained. It shows a difference of one-fourth more weight in the European over New Zealand of the same size yarn, which is the cause of greater elasticity in the latter.

The testing qualities of Russian hemp rope, when properly manufactured, are 1 cwt. for a 25 spun yarn, or 3 tons 15 cwt. for a 3-inch rope, to stretch one-twentieth of its length with this pressure. Tarred rope made from New Zealand flax has lately been sold at 26*l.* a ton in Sydney, and white rope at 42*l.*, while Manila fetches 49*l.* a ton.

Different experiments were made in 1871 at Wellington, to ascertain the durability and wear of New Zealand, as compared with Manila rope. The ropes were run over pulleys fixed on a horizontal shaft at Messrs. Kebbel's mill, and through a block below, to which a 56 lb. weight was attached. The circumference of the pulleys was 15¼ inches, grooved out to a diameter of 2½ inches. The ropes were wetted with salt water poured on them till they could absorb no more, and the wetting was repeated every fourth day after the ropes had apparently dried. The New Zealand ropes were machine-made, from Lloyd's Steam Rope Works near Auckland, and valued at 45*l.* per ton. The Manila was purchased in Wellington, and was the best of the size

(1·43-inch) that could be procured. The results showed that the New Zealand white rope, when kept dry, will last 60 per cent. longer than tarred rope of the same make, and 34 per cent. longer than the Manila, but chafes more by 10 per cent., and is more susceptible to change of weather. When wetted with salt water, the Manila lasted better than New Zealand by 10 per cent., but had 5 per cent. excess of shrinkage.

The fibre is chiefly used for rope making, and varies in price, according to quality, from 36*l.* 10*s.* to 20*l.* per ton, and lower qualities, called half-dressed, from 18*l.* down to 14*l.* per ton. In preparing the article for rope making, the points to be kept in view are: to have the fibre of good colour, as thoroughly as possible cleaned from straw and from the gum which exists in it, and to preserve its natural strength.

Other useful Fibres.—Most of our tropical colonies abound with valuable textile plants, some of which are considered troublesome weeds. Those of a ligneous nature will annually produce two crops of shoots, from which good fibre may be obtained, requiring no machinery whatever in preparing it for market. The most easy and simple plan is to macerate the shoots until the cuticle or outer bark disadheres freely from the epidermis or true bark, when the latter will separate readily from the ligneous part, and requires but little labour or knowledge to wash, dry, and pack the fibre for market.

For the plantain, pinguin, and all similar herbaceous plants, machinery is absolutely necessary to separate and clean the fibre advantageously.

Many of the Hibiscus family yield strong and useful fibre. In India and in the Southern States of America, attempts have been made to utilize the fibre of the common ochro (*Hibiscus esculentus*); about three tons of this hemp can be raised on a single acre. The capsules are a good vegetable, and the roasted seeds are used as a coffee substitute. A piece of twelve strand cord made from ochro hemp, tested by the United States' agent against a piece of a similar kind and size made from Kentucky hemp, broke under a weight of 302 lb., while the dew-retted hemp rope, of the same size and number of strands, broke under a weight of 547 lb.

From the bark of one or two species of *Hibiscus*, indigenous to Australia, the natives manufacture durable rope for their nets, &c. *H. heterophyllus* is one of those straight growing shrubs with strong fibrous bark, that have obtained the common name of cordage trees in Tasmania. *H. liliaceus*, another species, is the plant from the bark of which the inhabitants of Tahiti make their cloth, ropes, and matting. Mahoe bark (*Hibiscus elatus* or *Thespesia populnea*) furnishes a very strong but coarse fibre in Demerara, which is used for making coffee bags, &c.

In India many of the malvaceous plants are extensively cultivated and highly esteemed for their fibre. The bark of *Hibiscus cannabinus* in Coromandel abounds in strong and tolerably soft fibres, which are employed as a substitute for hemp, and are made into a coarse sack cloth. In the north-west provinces of India, it is very generally cultivated for cordage, and for domestic and agricultural purposes, but its fibre is more remark-

able for fineness than for strength, and would be of use in our manufactories in making mixed fabrics.

Several species of the grass tribe (*Saccharum*) are employed for making ropes on the river Ganges or the Indus. For this purpose these fibres are well fitted, being light, tenacious, and capable of bearing without injury alternate exposure to wet and dry.

Dr. Forbes Watson, speaks favourably of an Indian grass called mounj (*Saccharum munja*), abundant in Scinde, where it is used for making tow ropes for the native boats on the River Indus. It supplies a strong good fibre, which is beginning to attract attention in this country, and is being exported from Kurrachee.

Of the sedges, a kind of cotton grass (*Eriophorum cannabinum*), which grows abundantly in all the ravines of the Himalayas, is platted into the ropes of which the jhoolas or rope bridges over the large rivers are almost universally made.

Gomuti or Ejoo fibre (*Arenga saccharifera*) is considered superior in the East to all others yet made use of for the manufacture of artificial tresses, imitation horse-hair for stuffing, and such like purposes.

The stalks of *Apocynum cannabinum* and *hypericifolium*, afford the North American Indians a substitute for hemp, of which they make twine, bags, and fishing nets and lines; and also linen for their own wear.

The roots of *Butea frondosa* and *superba* are made into strong rope in India. *Saguerus Rumphii* yields a fibrous web very fit for cables and long cordage. From the leaves of the oil palm (*Elais guineensis*), and wine palm, the natives make excellent line and rope in

West Africa; indeed it is from this that they produce all their fishing lines and nets. In the Cape Colony various species of *Restio*, known under the common name of rope grass, are in frequent use for cordage.

The fibre and rope made from the wild Rheea (*Urtica*) or nettle species, are among the strongest known, but it is too dear to come into the markets as a rope-making material. In testing it in a rope manufactory its strength per square inch was found to be 844, 894, and when made with the fibre 900.

The average strength of rope made with the best hemp was determined after many experiments carried on between the years 1803 and 1808 to be 805.

In December, 1853, some experiments were made at the East India Company's military stores, with fibres in equal weights and of equal lengths, when the following results were obtained:

	Broke with
Petersburg clean hemp	160 lb.
Jubbulpore hemp (*Crotalaria tenuifolia*) ..	190 „
Travancore hemp (*C. juncea*)	175 „
Mudar or Yercum fibre (*Calotropis gigantea*) ..	190 „
China grass (*Boehmeria nivea*)	350 „
Rhea fibre (*Urtica sp.*) from Assam	320 „
Wild Rhea „ „	343 „
	No breakage at
Hemp from Koti Kangra, Sikh Himalayas ..	400 lb.

The Moorgha or Marool (*Sanseveira zeylanica*) fibre is remarkable for its whiteness. A line 4 feet long, made of this fibre, according to Roxburgh, bore a weight of 120 lb., when a cord of the same size made of Russian hemp bore only 105 lb. The former, more-

over, after 116 days' maceration bore a weight of 30 lb., when the latter was completely rotten. Some ropes made from it, tried by the master-attendant at Calcutta, broke at 137 lb., while Manila hemp took 188 lb. to break it. It may be considered about the same strength as agave fibre.

Large quantities of the fibrous bark of the lime tree are used for making cordage and mats in Russia, which contains extensive forests of the tree. About fourteen millions of mats are made annually, of which one-fourth are shipped to England.

JUTE.—The well-known jute of commerce now occupies a most important position amongst the supplies of textile materials furnished to this country, our receipts being 200,000 tons. There are two species which afford the fibre, viz. *Corchorus capsularis* and *C. olitorius*. It is very largely cultivated throughout the Bengal Presidency, and is much used for bags, and for baling or packing cottons, which each weigh about 2 lb.; and is also shipped in pieces of about 30 yards, called gunnies, which weigh on an average 6 lb.

A mixture of jute with flax or hemp is easily detected by submitting the suspected material for about four hours to the action of steam at a high pressure; in washing, the jute destroyed by this means will easily separate from the fabric, while the flax or hemp remains unaltered.

As it takes about 6 yards for wrapping every bale of cotton, a crop of 3,500,000 bales of American cotton requires 21,000,000 yards of bagging. One third of this supply is usually imported as gunny cloth from

Bengal; and what is used for other packing purposes is chiefly hemp bagging. The manner in which the jute trade of Calcutta continues to increase is very remarkable. The total exports of jute and jute cuttings in 1872 slightly exceeded 2,000,000 bales. In 1863 the shipments were only about 800,000 bales, whilst ten years earlier scarcely 20,000 bales were exported. Of the 2,000,000 bales shipped in 1872 the United Kingdom took about 1,500,000; the Continent, 14,000; and the United States, 450,000 bales. But even then these exports do not represent the total quantity of jute produced and brought to market, for besides a considerable quantity consumed locally, upwards of 106,000 pieces of gunny cloth and 28,000,000 gunny bags, averaging about 2 lb. each, were exported.

Wire Ropes and Cordage.—Amongst the various branches of our great iron industry, the manufacture of wire ropes and cordage ranks as one of the wonders of modern enterprise, and one of growing importance. The invention of wire rope is to be credited to the late Mr. G. W. Binks, of Poplar, who, in the year 1830, was foreman ropemaker in the Woolwich Dockyard, having from apprenticeship served some thirty-four years in the Government employ. Our complications with Russia and a failure of the hemp crops operated so seriously upon the price, that the Admiralty was paying 80*l.* per ton for hemp. This turned the attention of the Government to inquiries whether some other and cheaper rope might not be substituted for *hemp*, and under their direction Mr. Binks made in-

numerable experiments with various cordage, even spinning ropes from the fibre of the common nettle. Nothing, however, seemed to possess the many excellent qualities of hemp.

Thinking over the matter at home, the idea struck Mr. Binks of twisting together fine iron wires to form a rope, and he made a specimen—still preserved—which he submitted to the Admiralty officials, who, however, did not approve of it. Captain George Harris, of the Royal Navy, alone thought that there was in this specimen the germ of a great and important manufacture, and, taking Mr. Binks by the hand, he established a manufactory on a small scale at Grimsby in 1835. Space will not permit me to relate the repeated instances of opposition which they had to contend against with this new manufacture, even from the Admiralty itself. Just as some encouragement appeared, Captain Harris, whose capital and influence were the life and soul of the new manufacture, died, leaving Mr. Binks alone to develop the trade. In this position George Binks was glad to enter into partnership with a practical man, who brought with him new machinery specially adapted for the process. He, however, patented the various samples of the manufacture in his own name, which led to a rupture, and thenceforward there were two rival businesses. Step by step, gaining ground, George Binks fought his way in popular favour, and a great demand sprang up, yielding fair profits.

Iron wire ropes were first conceived and used for the standing rigging of ships. The first vessel rigged

with wire rope as an experiment was the 'Marshall,' of Great Grimsby. But now the uses of wire ropes are innumerable. Amongst the most prominent are—ships' standing and running rigging; submarine telegraph cables; suspension bridges; guide, incline, and flat ropes for mining purposes; special forms of rope for engineering purposes; pneumatic telegraphs; traction ropes for tramways; steel plough ropes; coulippe ropes for transport of sugar canes, &c.; tent stay ropes; ropes for hoisting purposes; tow ropes; endless driving bands; bullock traces; telegraph running and stay strand; fencing strand; scaffold ropes; railway signal cords; clock lines; clothes lines; sash lines; lightning conductors; gilt and silvered cords for hanging pictures; and many other applications might be enumerated, whilst for all these purposes they are stronger, lighter, cheaper, and more durable than any other article. They are made from cast, homogeneous, and Bessemer steel, from charcoal and common brands of iron, bright or annealed, and from copper and brass; and are produced in a multitude of varied forms, with from one to very many strands, with hempen cores or without, or with covered wire, and in gauges of wire from those as fine as a hair to those of the thickness of one's finger. When we find that there are over thirty wire rope manufactories in existence, large and small, employing a very large number of hands, the importance of the trade will at once be recognized. Many considerable steps in modern progress, such as submarine cables, suspension bridges, &c., could not have been *effected* without the aid of this principle, whilst thou-

sands of pounds and thousands of lives have been saved by the adaptability of wire ropes to shipping and mining purposes.

In some experimental tests, instituted at the Corporation testing machine at Liverpool, to ascertain the comparative strength of wire and hempen ropes for the standing rigging of ships, the following were the sizes and materials of the samples subjected to experiment, with the results :

		Broken at tons.	cwt.
3¾-inch	galvanized wire rope	29	15
3¾ „	Manila hemp	5	17
3¾ „	Russian hemp	4	15
3¼ „	galvanized wire rope	16	16
2¼ „	„ „	8	16

There were also some experiments made with soft and hard wire rope, the whole series being as satisfactory to those present as they must have been to the manufacturers, who proved, by this best of all methods of proof, that their ropes withstand a strain considerably beyond their trade lists and the Admiralty tests of strength.

The straining tests show the immense superiority of wire rope over that made even of the best fibrous material; but this is not the sole or indeed the greatest of the advantages which it presents. Wire rope is a fourth less in weight and not one-half the bulk of that made of hemp of the relative strength and enduring capacity. The advantage of this, especially in beating to windward, needs no comment. Moreover the cost is 25 per cent. in favour of wire rope over hemp, estimating

weight and saving. Again, wire rigging is much less susceptible than hemp to atmospheric changes, the latter continually stretching; and when, in addition to all these advantages, it is remembered that wire rigging needs no stripping or refitting, as hemp rigging must have every four years, we cannot but come to the conclusion that wire rope seems destined ere many years greatly to surpass, if it does not supersede, hemp rope in ships' standing rigging.

The following figures show further the great superiority of wire ropes over those of hemp, which they surpass even in flexibility:

Wire Rope.		Hemp Rope.		Equal to strain of cwts.
Size.	Weight per fathom.	Size.	Weight per fathom.	
in.	lb. oz.	in.	lb. oz.	
3	2 4	1¼	1 4	50
4	3 15	1½	1 9	70
5	6 0	1¾	1 14	135
6	9 0	2	2 2	160
7	12 3	2¼	2 9	171
8	14 3	2½	4 1	198
9	19 6	3	5 4	306
10	25 0	3½	7 1	486
11	30 0	4	11 6	585
12	36 8	4½	15 12	704

The twisting, it is stated, should not be so hard as in hempen cordage, and all the wires must be protected by an anti-corrosive composition, or by coating with tin, zinc, &c. It is sometimes the practice to twist wires round a core either of wire, hemp cord, *spun* yarn, or other material, to form a strand, and to

lay such strands round a similar core, when there are more than these strands in a rope. Ropes of twisted iron wire were used in the silver mines of the Hartz Mountains nearly fifty years ago; they were nearly equal in strength to solid iron bars of equal thickness, and equal to hempen ropes many times their weight.

Mining engineers differ as to the best form of winding ropes for mines, many being adverse to the use of flat ropes, especially of stout wire. At the Bruckenberg shaft near Zwickau, Saxony, two flat steel wire ropes have been in use for some time past. This shaft is 437 fathoms in depth, requiring ropes strong but light.

The house of Felton and Guillaume, of Cologne, made two flat steel wire ropes, nearly 5 inches wide, 1 inch thick, and 492 fathoms in length, weighing about 23 lb. per fathom. They were formed from 7 round wire ropes placed side by side, united by a wire of 3 strands, each of 4 No. 14 wires. Each of the 7 round wire ropes was formed of 4 round strands, each composed of 7 wires surrounding a hempen cord. The breaking strain of the cable was 105 tons. After 426 days' use the wear was limited to the wire uniting the 7 ropes, which required renewing, and the total cost per ton raised did not exceed one penny. These results indicate considerable economy from the employment of flat ropes in deep shafts.

The value of the British-made iron and steel wire shipped has doubled in the last ten years, and is progressively increasing. The exports were—

1870	.. ..	23,447 tons, valued at	£439,546
1874	.. ..	36,692 „ „	769,927

In addition, telegraphic wire was shipped in 1873 and 1874 of the average commercial value of upwards of 2,000,000*l.*

Cotton Cordage.—However long cotton may have been used for cordage in India, it is only latterly that the manufacture has been carried on in the United States. The American Cordage Company of New York, and some other manufacturers, make cotton rope for rigging, tow lines, cordage, &c., and in this country it is coming into use for fishing nets, lines, &c. A machine is made to answer all the purposes of a long ropewalk. Cotton is capable of a tighter twist and is less injured by friction than hempen cords. The rope is more pliable, and runs more freely through the blocks than hemp rope; and the fibres are laid together more compactly, with greater tension, by this process. The cotton used is a long staple Macon Georgia.

Esparto Cordage.—Cordage made from esparto is largely exported from Spain to France, Italy, Holland, Portugal, the United States, and England. The port of Lake Aguilas, near Carthagena, ships about 20,000 tons of different kinds of fabrics made of it, and those on the coast from Alicante to Almeria about 5000 tons. No less than 50,000 persons are employed in the twisting of this fibre in the two last-named districts, principally young girls and children; but it is very roughly made. The Spanish marine and mining industries employ a great quantity of cordage made with esparto, which costs about 10*l.* to 12*l.* the ton.

Hide Rope.—The manufacture of hide rope is carried on to some extent, and is made in the following

manner: The hide being limed and freed from hair is placed upon a round table, when the workman, with a knife made for the purpose, shaves off the extreme portions, such as the shanks, cheeks, and the like, until the hide is comparatively round. He then commences to cut a strip of the required width, which he continues in one length until the whole hide is cut up. A number of the strips thus made are taken and stranded or plaited together, according to the thickness of the required rope. The rope thus far completed is then submitted to the action of a solution, which preserves the animal substance, and renders it soft and pliable. Hide ropes are used for hoisting purposes in warehouses and mines, and form a good substitute for a chain. Sailors approve of hide for tiller ropes, because it does not make the rattling noise of iron, and if it should happen to break, the rupture is not so sudden, and therefore time is afforded to meet and provide, to a certain extent, for the threatened calamity. It is not affected by humidity or extreme dryness, like Manila and hempen rope, and its tenacity being tenfold greater, it is less cumbersome, and consequently lighter. In the colonies it is often used for halters and traces.

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